ASTRONOMY

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The Vanishing Act of Red Giants

An Eclipse Chaser's Notebook

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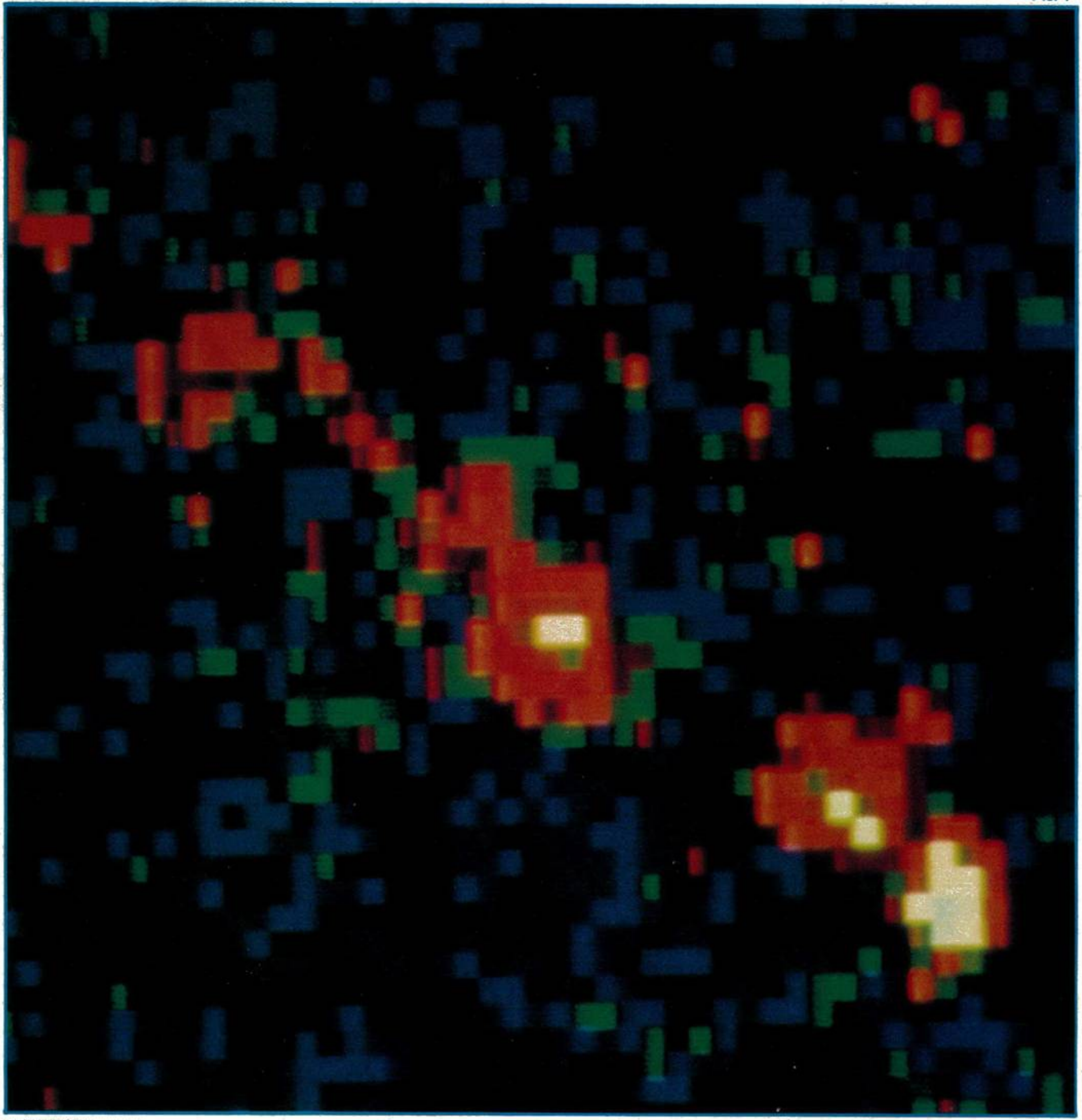

Decoding the Electromagnetic Spectrum

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Dr. John C. Diebel, President
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Dear Dr. Diebel:

We have enjoyed some excellent 'seeing' recently, so last night I was delighted with the chance to do some serious observing through my Meade 2080.

I tried the double star Castor first—a fairly nasty test for glare and scatter, as the components are both bright and close. While the 2080 resolved this double with ease, the thing I particularly noticed was the Airy disc—smaller, harder, and sharper than in other Schmidt-Cassegrains I've observed with, and I've observed with them all at one time or another. Even at 450X, the stellar diffraction rings were very well formed and symmetrical.

Then I tried the first-quarter Moon. Here the 2080 won hands down for image contrast over other Schmidt-Cass's I've used. Your baffling really works! At powers from 200X to 450X, the image was extremely sharp and the resolution excellent.

Finally, I aimed the 2080 at Jupiter and noted (a) very good contrast between the planet and the sky background, and (b) the same high contrast ratio between the cloud belts and the brighter portions of the planet's disc. There is little doubt in my mind but that the 2080 is a very high-performance instrument. In sum, I am impressed.

Yours very truly, Leo Henzl

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Telescopes Shown: *(top) Meade 8″ Model 2080 with optional photographic systems; and (bottom) Meade 10″ Model 2120 with optional 2″ f/12 Photo-Guide Telescope.*

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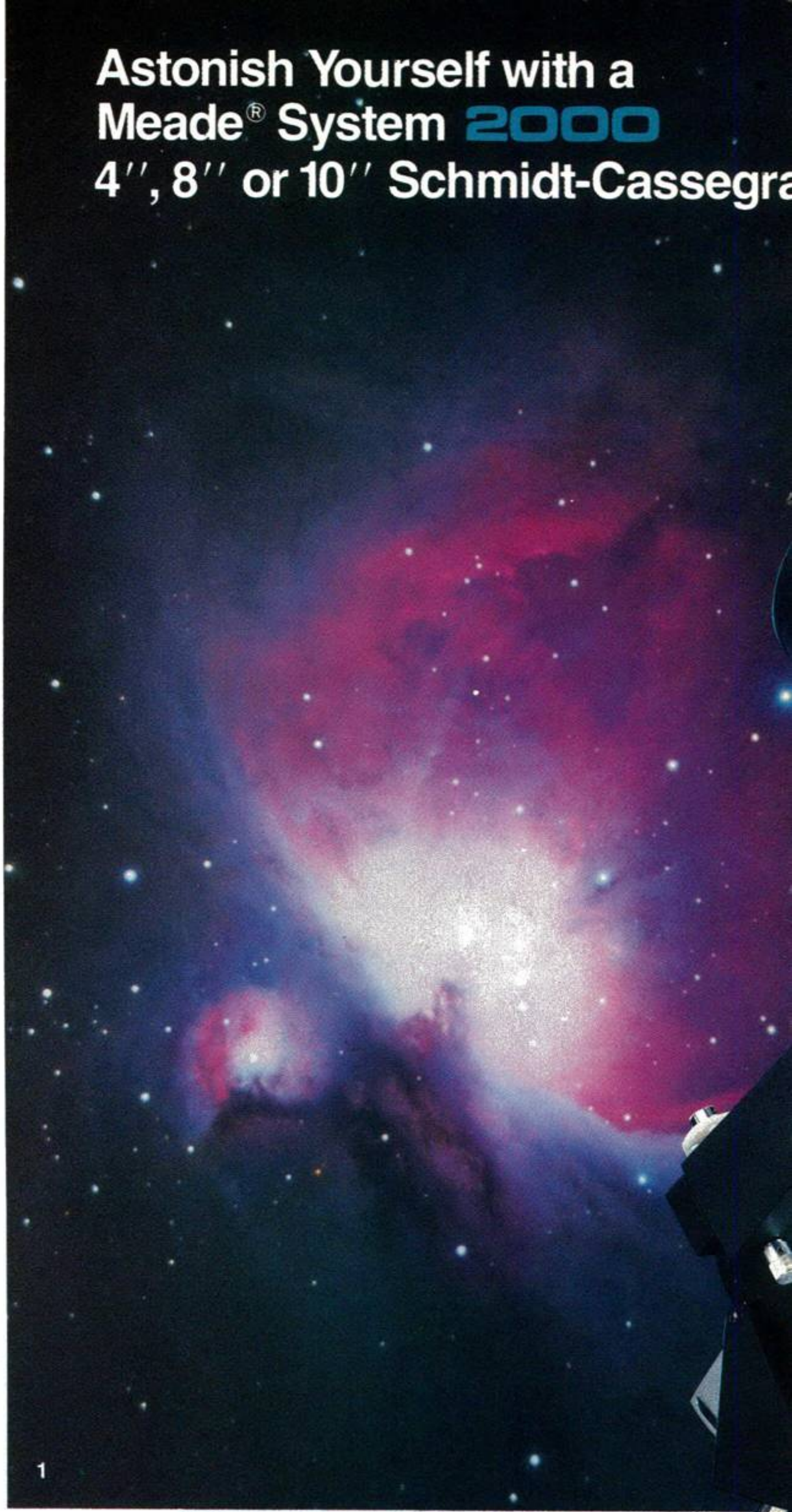

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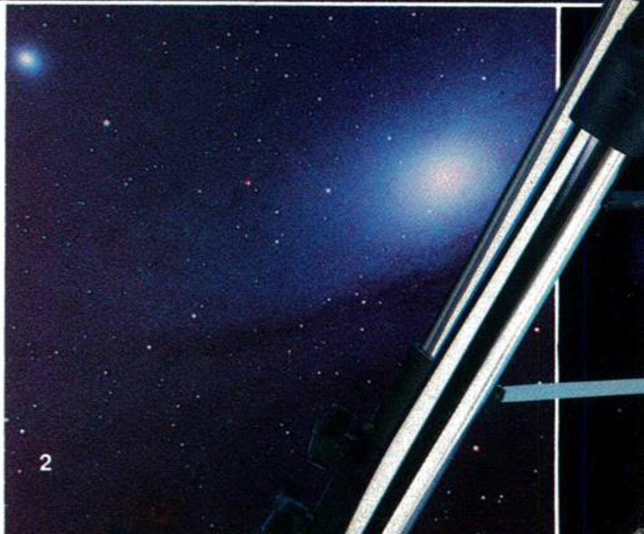

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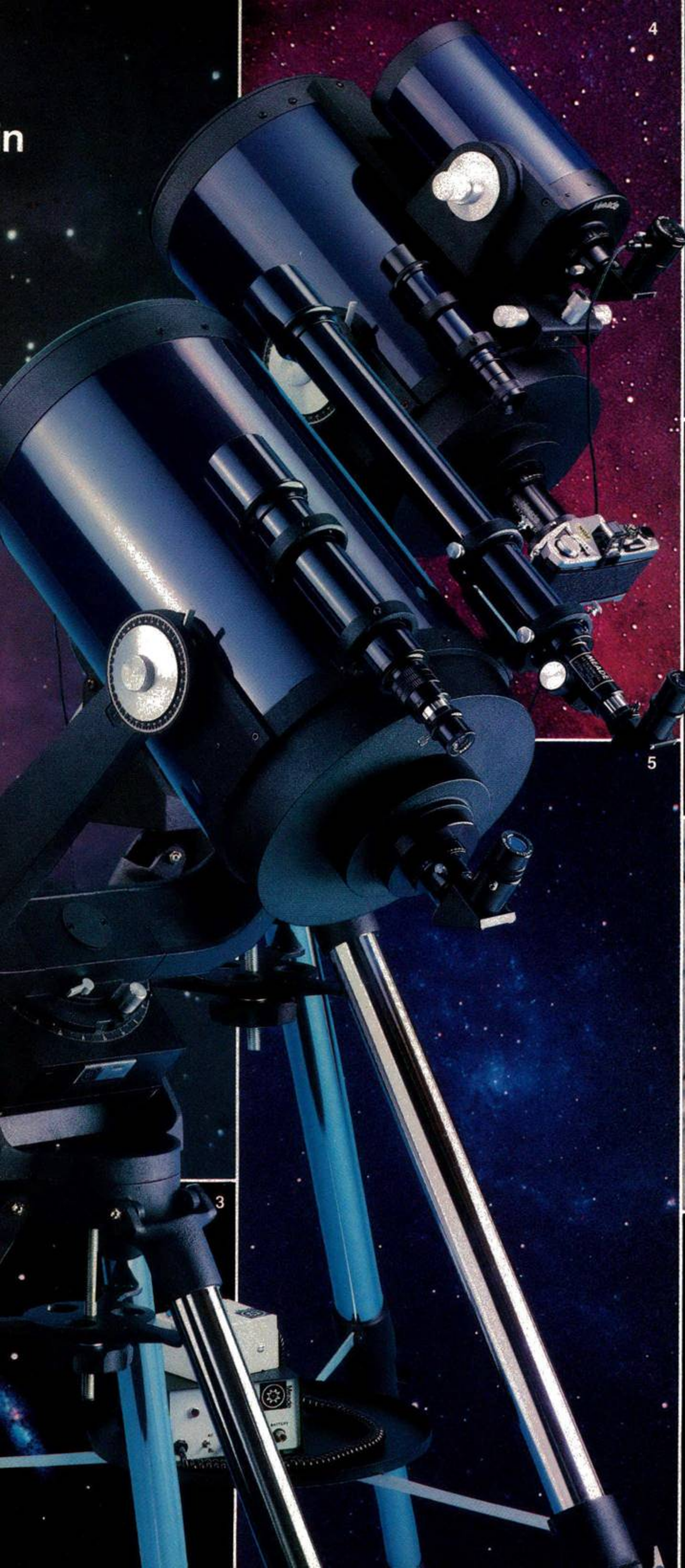

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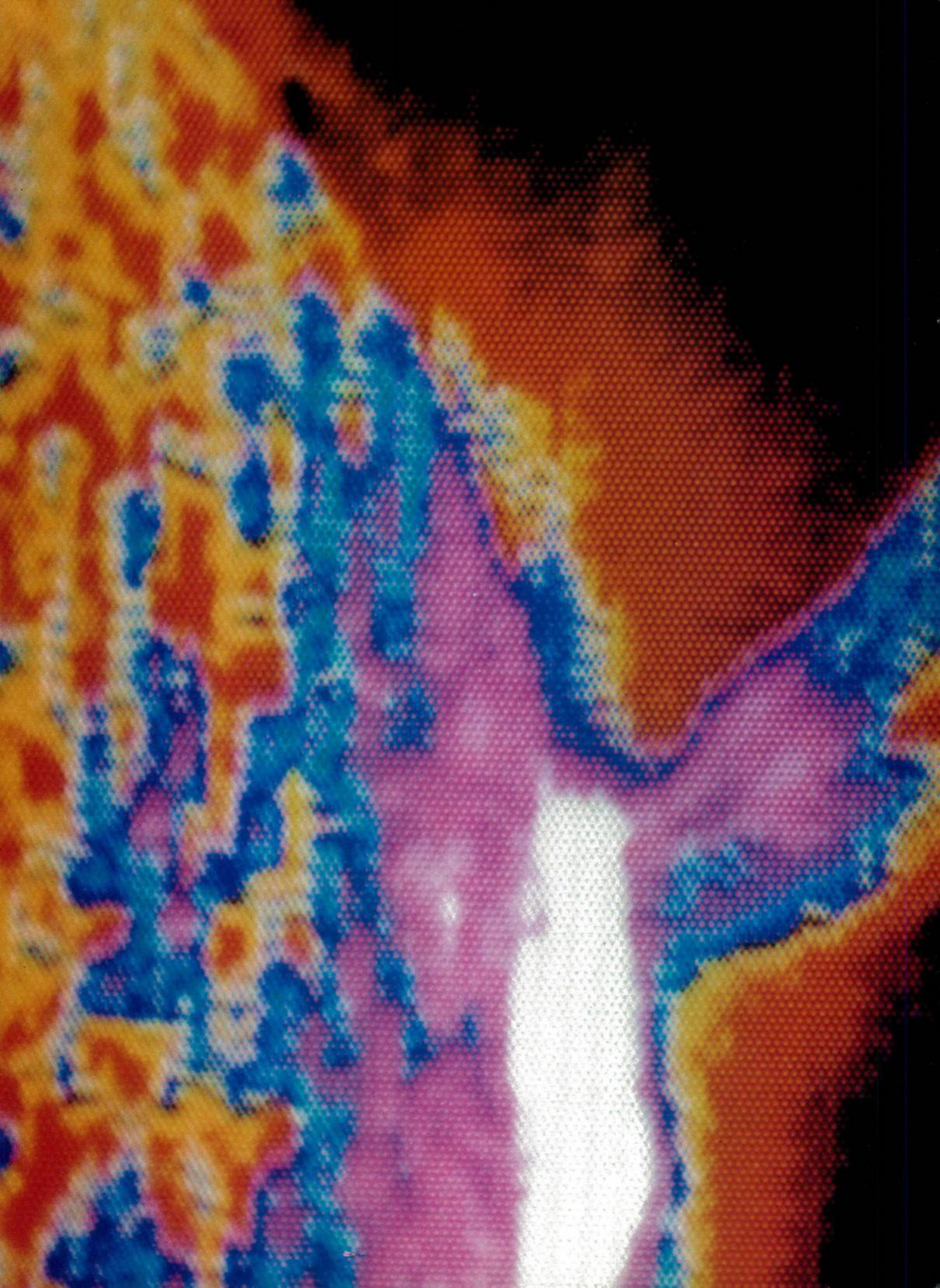
All astrophotographs shown on these pages were taken through off-the-shelf, unmodified Meade 8″ Model 2080 Schmidt-Cassegrain telescopes. For further technical details on these and many other astronomical photographs, send for your free copy of the Meade Schmidt-Cassegrain Astrophoto Brochure. (Alternately, the complete Meade 52-page General Catalog is available at $3.00 by First Class Mail and includes the Astrophoto Brochure at no additional charge.)

Key to Photographs
1, 2, 3, 5, 7 — Leo Henzl; 4, 6, 8 — Emery Hildebrand;
9 — John Sanford

1. Orion Nebula M42; exposure time 50 mins. **2.** Andromeda Galaxy M31; 60 mins. **3.** Galaxy M82; 60 mins. **4.** Milky Way in Sagittarius (50mm piggyback photo). **5.** Spiral Galaxy M33; 75 mins. **6.** Spiral Galaxy M51; 60 mins. **7.** Galaxy NGC 253; 40 mins. **8.** Omega Nebula M17; 40 mins.; **9.** Moon — Clavius region; 1-sec.



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Cover: When we look up at the night sky, we may feel that the "optical universe" is the entire universe. But what we see is only a fraction of what's out there. Both the X-ray image of the galaxy Centaurus A on the cover and the highly-processed ultraviolet image of a solar prominence on these pages bear witness to physical processes unseen or unsuspected just a few decades ago. This month's opening story takes you beyond the visible part of the electromagnetic spectrum and explores the ways that astronomers decipher the enigmatic messages of atoms in space. Cover image courtesy of HCO/SAO Center for Astrophysics; these pages, NASA.

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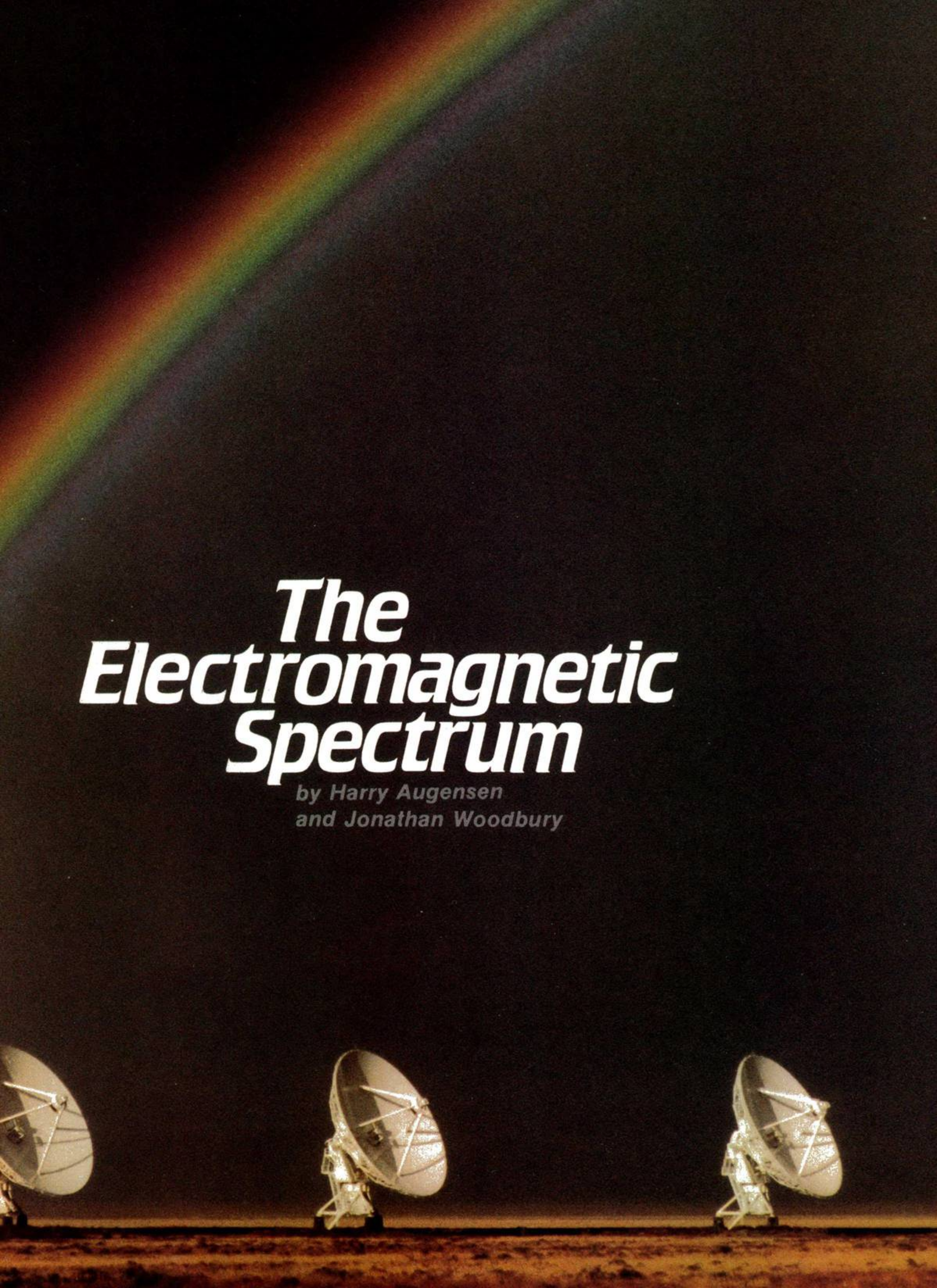
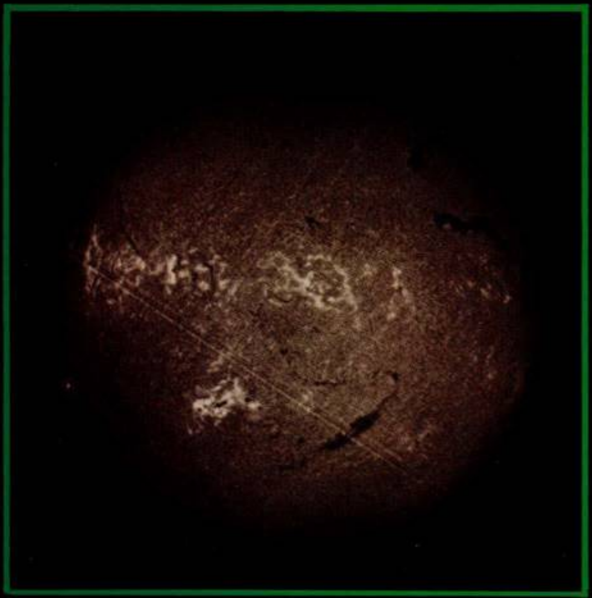
ABC

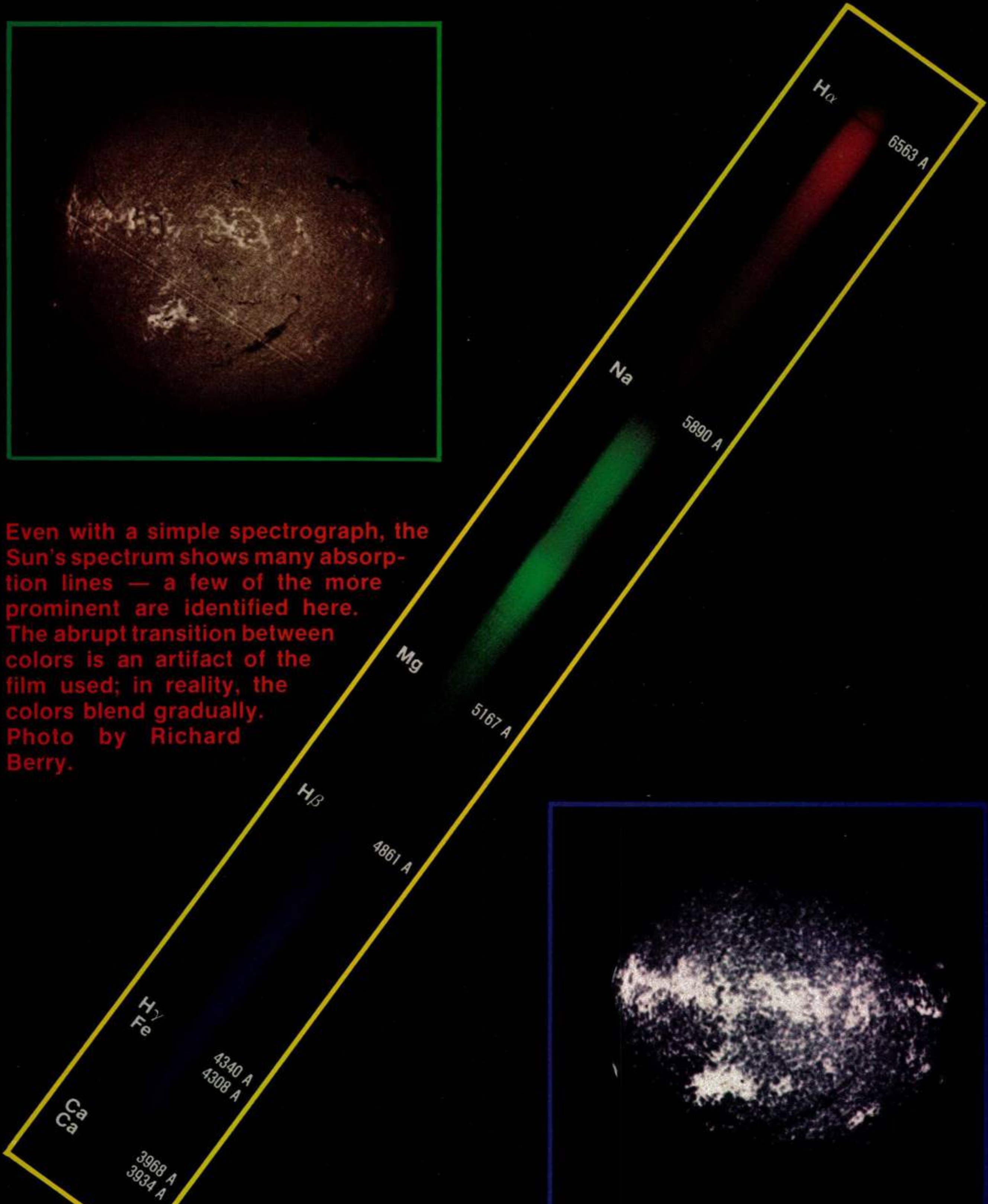
Photo © 1981 by Doug Johnson, Battelle Observatory



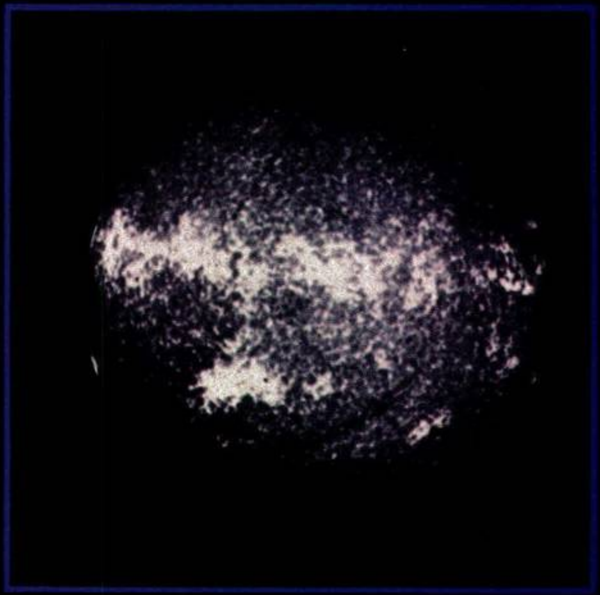
The Electromagnetic Spectrum

by Harry Augensen
and Jonathan Woodbury




Hα
6563 A
Na
5890 A
Mg
5167 A
Hβ
4861 A
Hγ
Fe
4340 A
4308 A
Ca
Ca
3968 A
3934 A

Even with a simple spectrograph, the Sun's spectrum shows many absorption lines — a few of the more prominent are identified here. The abrupt transition between colors is an artifact of the film used; in reality, the colors blend gradually. Photo by Richard Berry.



Viewed in the blue light of calcium, the Sun shows features differently than it does in the red light of hydrogen (above). Solar photos courtesy of Hale Observatories.

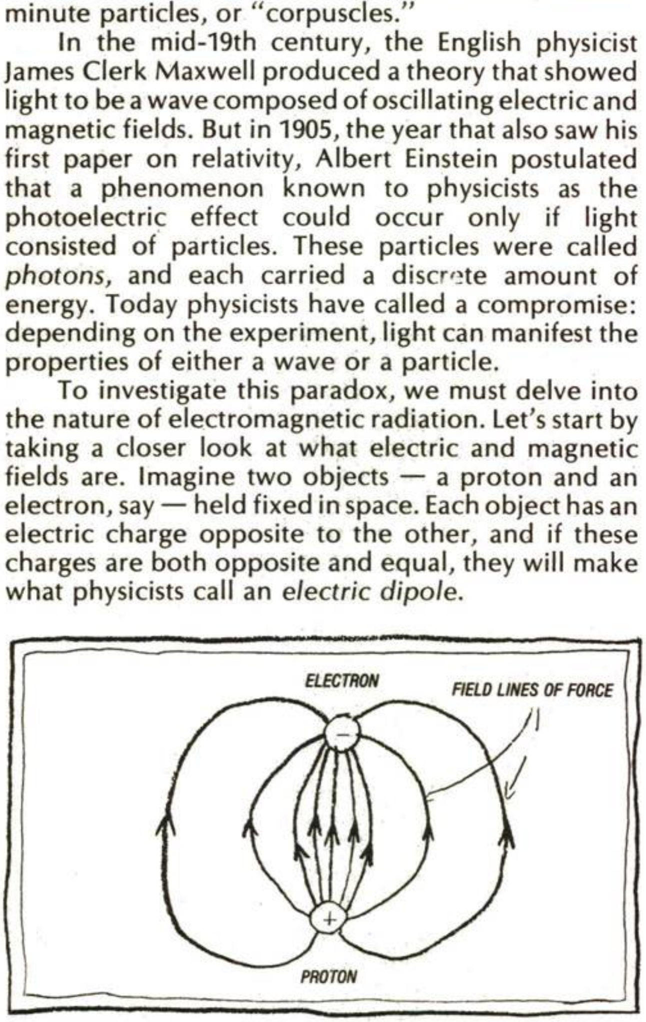
Have you ever wondered how astronomers decide that such and such a quasar lies, say, 14 billion light-years from Earth and is moving away at nearly the speed of light? Or how they know that the object at the heart of the Crab Nebula has an intense magnetic field? Astronomers also seem to know what stars are made of. And they tell us that Algol, which appears as a single star even in the largest telescope, is actually three stars orbiting a common center. How do they know all this? How can astronomers tell us so much about objects that are so far away?

The answer is that light — or more precisely, electromagnetic radiation — which streams across the void of space to Earth, contains not just a visual image but also many "coded" messages. These reveal much about physical processes in the objects that emit them. Once captured with a telescope, the message from a given object can be decoded by one or more devices such as a spectrograph, a polarimeter, or a photometer. But before they could construct such analytical devices, astronomers first had to understand just what light and radiation are.

Throughout most of history, the nature of light has provoked debate. But by the late 17th century, experiments by the Dutch natural philosopher Christiaan Huygens led him to put forth a theory that light was best described as something that behaved like a wave. On the other hand, his younger contemporary Isaac Newton asserted, on the grounds of his experiments, that light had to be composed of minute particles, or "corpuscles."

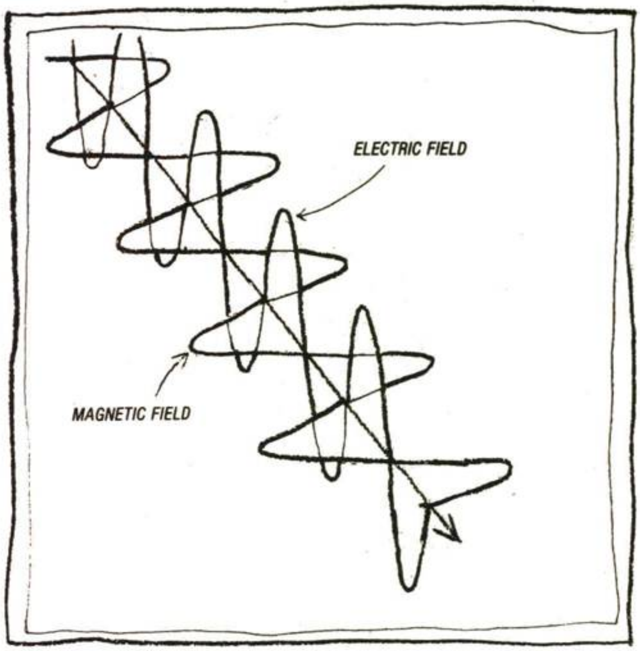
In the mid-19th century, the English physicist James Clerk Maxwell produced a theory that showed light to be a wave composed of oscillating electric and magnetic fields. But in 1905, the year that also saw his first paper on relativity, Albert Einstein postulated that a phenomenon known to physicists as the photoelectric effect could occur only if light consisted of particles. These particles were called *photons*, and each carried a discrete amount of energy. Today physicists have called a compromise: depending on the experiment, light can manifest the properties of either a wave or a particle.

To investigate this paradox, we must delve into the nature of electromagnetic radiation. Let's start by taking a closer look at what electric and magnetic fields are. Imagine two objects — a proton and an electron, say — held fixed in space. Each object has an electric charge opposite to the other, and if these charges are both opposite and equal, they will make what physicists call an *electric dipole*.



This dipole sets up an electric field that has a shape much like the magnetic field surrounding a bar magnet. Do you recall the experiment in grade-school science class where you placed a sheet of paper over a bar magnet and sprinkled iron filings onto the sheet? Responding to the magnetic force, the filings lined up in a pattern that showed the structure of the field. If we could see their lines of force, electric dipoles would show a similar structure.

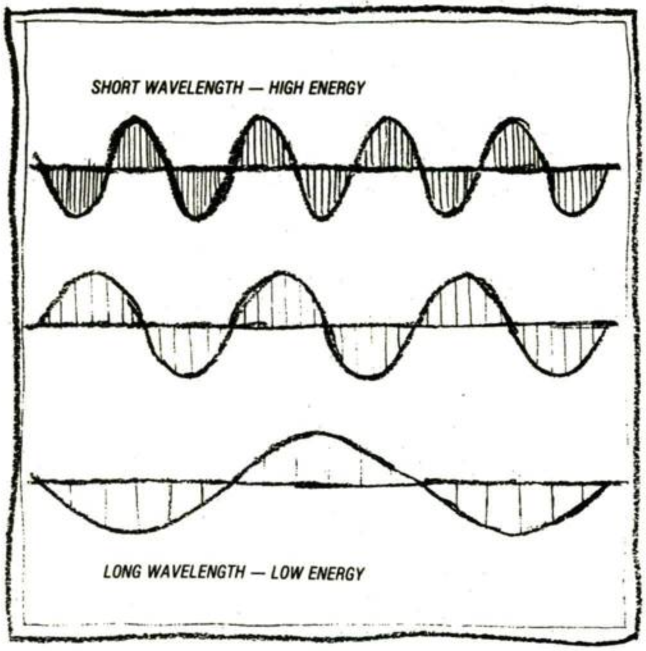
Physicists now think that light — and all electromagnetic radiation — is composed of a pattern or train of electric and magnetic fields which oscillate at right angles to each other and to the direction of their travel. One entire *wave train* constitutes a photon that moves through space at the velocity of light — 300,000 kilometers per second. If you were standing in space and watched the wave pattern move past, you would see the electric field of the wave oscillating in magnitude and direction. The wave's magnetic field oscillates in a similar fashion, but perpendicular to both the electric field and the direction of motion.



The distance between two successive crests of the wave defines the *wavelength* of the radiation. If this crest-to-crest distance lies between 0.0004 and 0.0007 millimeters, the human retina can sense the radiation: we call it light. Radiation with wavelengths shorter than those in this range is labeled ultraviolet, X-ray, or gamma-ray radiation. Radiation with wavelengths longer than those of light waves is called infrared, microwave, or radio radiation.

The electric and magnetic fields that make up the wave train store energy which they transport from the source. The waves which compose X-rays and ultraviolet radiation are more densely "packed" than those of visible radiation and hence they transport more total energy. Infrared and radio waves, on the other hand, are less densely packed than visible waves, and so do not carry as much energy for a wave train of the same length.

You might think of these varying wavelengths as



bullets of different densities fired from the same rifle. Those composed of iron or lead can penetrate a target more deeply than bullets of plastic or wood, given the same velocity. Like lead bullets, X-ray photons are quite powerful and are capable of inflicting damage upon living tissue. Conversely, radio waves are so weak and tenuous that astronomers use enormous dish antennas to collect enough of their feeble energy to provide information regarding their source.

Keeping this basic outline of the structure of light in mind, we can better understand the radiation we see from stars — and how it is produced. When dealing with stellar radiation, astronomers often resort to a useful substitution — they assume that stars are *blackbody* objects. A true blackbody absorbs all energy that falls upon it and emits the same amount back into space — it is a *perfect radiator* as well as a perfect absorber. While stars are not quite true blackbodies since they do not emit perfectly (some of the outgoing radiation is absorbed in a star's atmosphere), the approximation is still good.

In 1900, the German physicist Max Planck discovered an exact mathematical relation that describes how much energy is emitted by a blackbody at a given temperature over all wavelengths. Planck's equation combined two other properties that had been noted years before by physicists. First, as the temperature of a blackbody increases, the radiation is emitted at shorter and shorter wavelengths — that is, the blackbody becomes bluer. Second, as the temperature of a blackbody increases, the total amount of energy emitted by each square centimeter of its surface increases exponentially. Thus, doubling a blackbody's temperature increases its radiation per unit area 16 times.

These effects were known as Wien's law and the Stefan-Boltzmann law, respectively. Wien's law is particularly important, since it tells us that objects much hotter than our Sun will be sources of ultraviolet and X-ray photons, while objects cooler than the Sun will emit mainly in the infrared and radio regions of the spectrum. But as we shall see later, this is true only of hot, or *thermal,* sources. Other processes allow some objects to be strong emitters of both X-rays and radio waves.

Until just a few decades ago, astronomers could study the universe only through the visible wavelengths of light. Why? For three reasons: first, the human eye is sensitive to wavelengths in this range; second, Earth's atmosphere selectively blocks out most radiation with wavelengths both shorter and longer than the visible; and, last, astronomers didn't have the technology for making sensitive detectors of X-ray, ultraviolet, infrared, and radio radiation until well into this century. The "traditional" universe was composed of objects which emitted large amounts of visible radiation: ordinary stars, galaxies, and gaseous nebulae. Planets and other cold objects, such as dust clouds, were visible only when they reflected or absorbed visible light.

But suppose we could survey the universe with eyes sensitive to radio waves, or infrared, or ultraviolet, or X-rays. What would it look like? Would the ordinary stars and galaxies still be prominent? Would new types of objects be discovered? Thanks to the rapid development of radio astronomy after World War II and to the advent of automated "observatories in orbit," astronomers can now draw a picture of the non-optical universe.

If we saw the sky through infrared eyes, we would still see many stars — in fact, some would be brighter than they are in visible light. These stars are the cool M-class giants; since they are cool, Wien's law decrees that they radiate most of their energy in the infrared.

We would also see bright hazy patches in regions where stars are forming. In the Orion Nebula, for example, very young proto-stars are radiating most of their energy at infrared wavelengths. Also, slightly older and much hotter stars that have fully "turned-on" are heating up the surrounding dust cloud from which they formed. This warm glow produces more long wavelength radiation.

Nor are stars and nebulae the only infrared bright inhabitants of the universe; some galaxies which contain much dust are also infrared sources. Finally, in our own "backyard," the planets of the solar system, warmed by visible light from the Sun, radiate some of what they absorb back into space at infrared wavelengths.

If we pushed farther down the long-wavelength side of the visible spectrum and into the radio region, the sky would be altered beyond recognition. We would find many intense sources, including dense molecular clouds, clouds of neutral hydrogen, the planet Jupiter, some planetary nebulae, the galactic center, shells of gas from old supernovae, pulsars, Seyfert and other peculiar galaxies, quasars, and the dim, fading glow left over from the Big Bang.

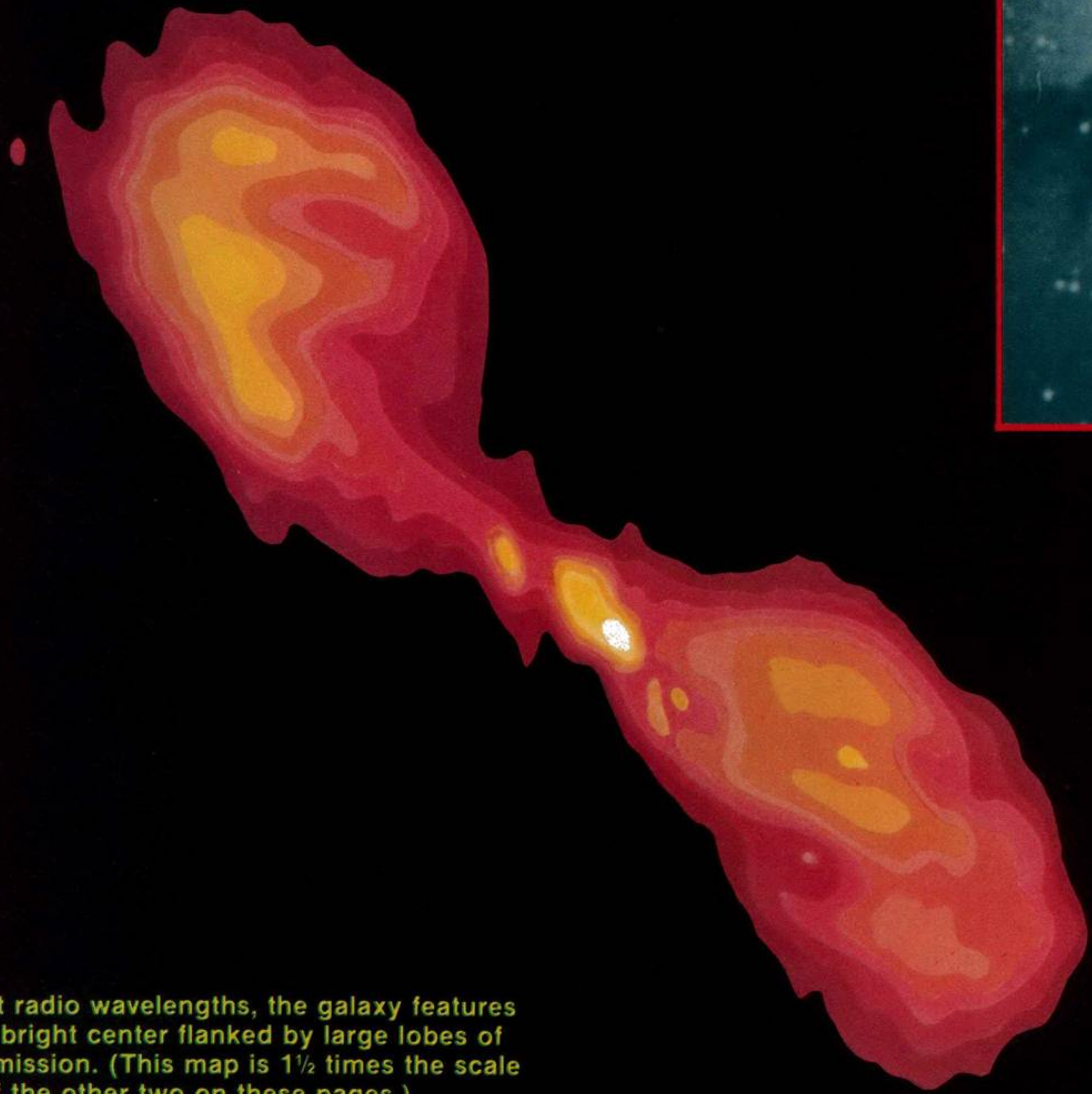
Although some of these radio sources are *thermal* — those that emit long wavelengths because they are relatively cold — others are *nonthermal,* and the radiation they emit is not at all characteristic of a blackbody. Instead, the emission from a nonthermal source comes entirely from electrons which are whirling at velocities near the speed of light in powerful magnetic fields.

Passing from the long to the short-wavelength

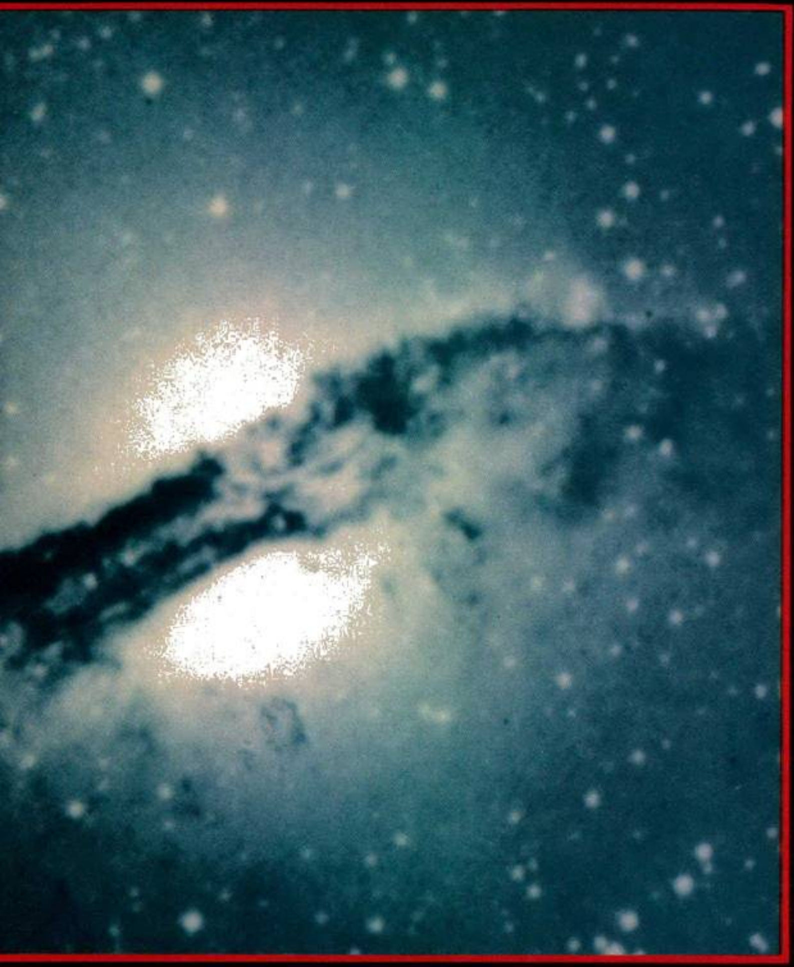
WAVE-LENGTH	FREQUENCY	TYPE OF RADIATION		PHYSICAL PROCESS	REPRESENTATIVE OBJECTS	DETECTORS	
10^{-5} Å	3×10^{23} Hz	GAMMA RAYS		Synchrotron and Thermal	Quasars Pulsars Neutron Stars X-ray Binaries Seyfert Galaxies Supernovae Solar Corona	Geiger Counters Scintillation Counters Nuclear Emulsions Cerenkov Light-Detectors	SATELLITE DETECTION
10^{-2} Å	3×10^{20} Hz						
10^{-1} Å	3×10^{19} Hz	X-RAYS					
10 Å	3×10^{17} Hz						
3000 Å		ULTRAVIOLET λ_{max} Sirius		Bound-Bound Synchrotron	O-B Type Stars Seyfert Galaxies Novae White Dwarfs	Photographic and Photoelectric Detectors Spectrographs Spectrometers	
4000 Å	7.5×10^{14} Hz	VISIBLE LIGHT	VIOLET	Free-Free	Normal Stars and Galaxies		EARTH-BASED DETECTION
5000 Å			BLUE λ_{max} Sun GREEN	Bound-Bound Synchrotron			
6000 Å			YELLOW ORANGE				
6600 Å			RED H-alpha				
7000 Å	4.3×10^{14} Hz		λ_{max} Betelgeuse				
10^{4} Å	3×10^{14} Hz	INFRARED		Bound-Bound Synchrotron	M-type Stars Proto-stars Planets Molecular Clouds		SATELLITE DETECTION
10^{7} Å = 1 mm							
10 cm	3×10^{9} Hz	RADIO WAVES	Microwaves	Synchrotron	Interstellar Molecules	Radio Telescopes	EARTH-BASED DETECTION
21 cm	1.4×10^{9} Hz		UHF	hyperfine	galactic hydrogen		
5 m			FM & TV	Thermal	Galactic Center		
50 m	10^{7} Hz		Shortwave		Supernova Remnants		
500 m			AM		Radio Galaxies		SATELLITE DETECTION
5 km	10^{5} Hz		Longwave		Seyfert Galaxies		

NGC-5128

a peculiar galaxy in Centaurus

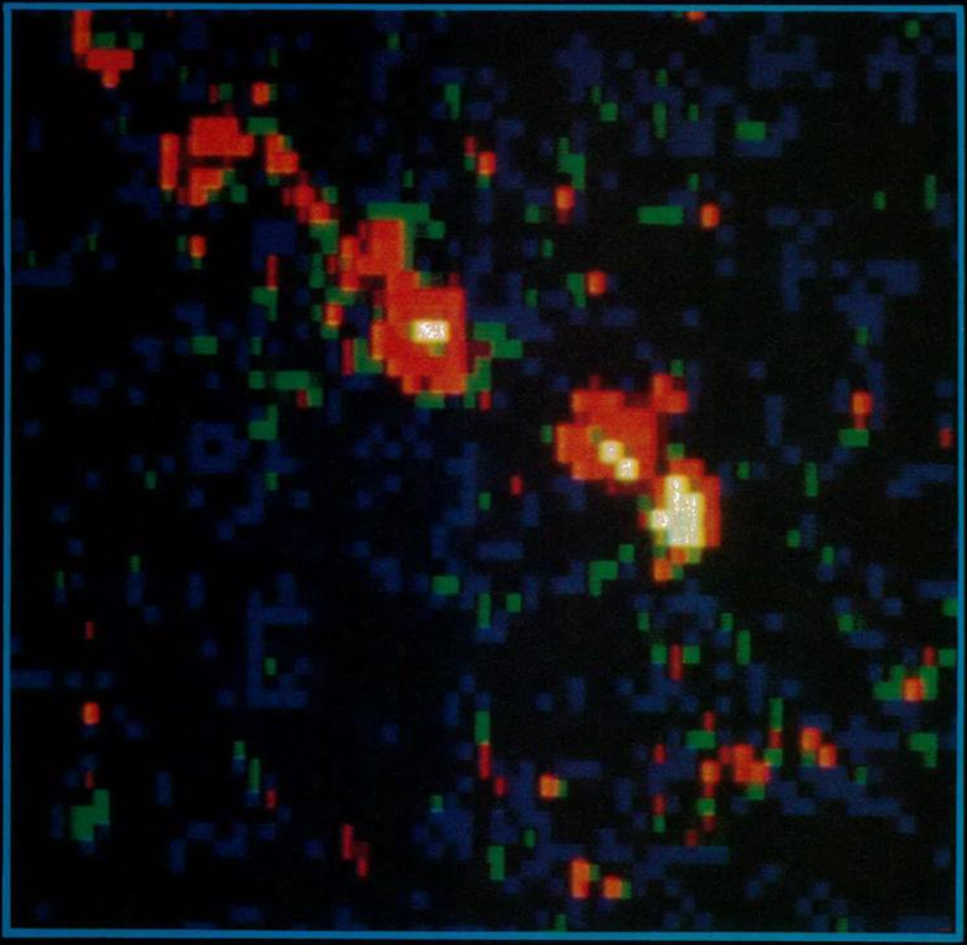


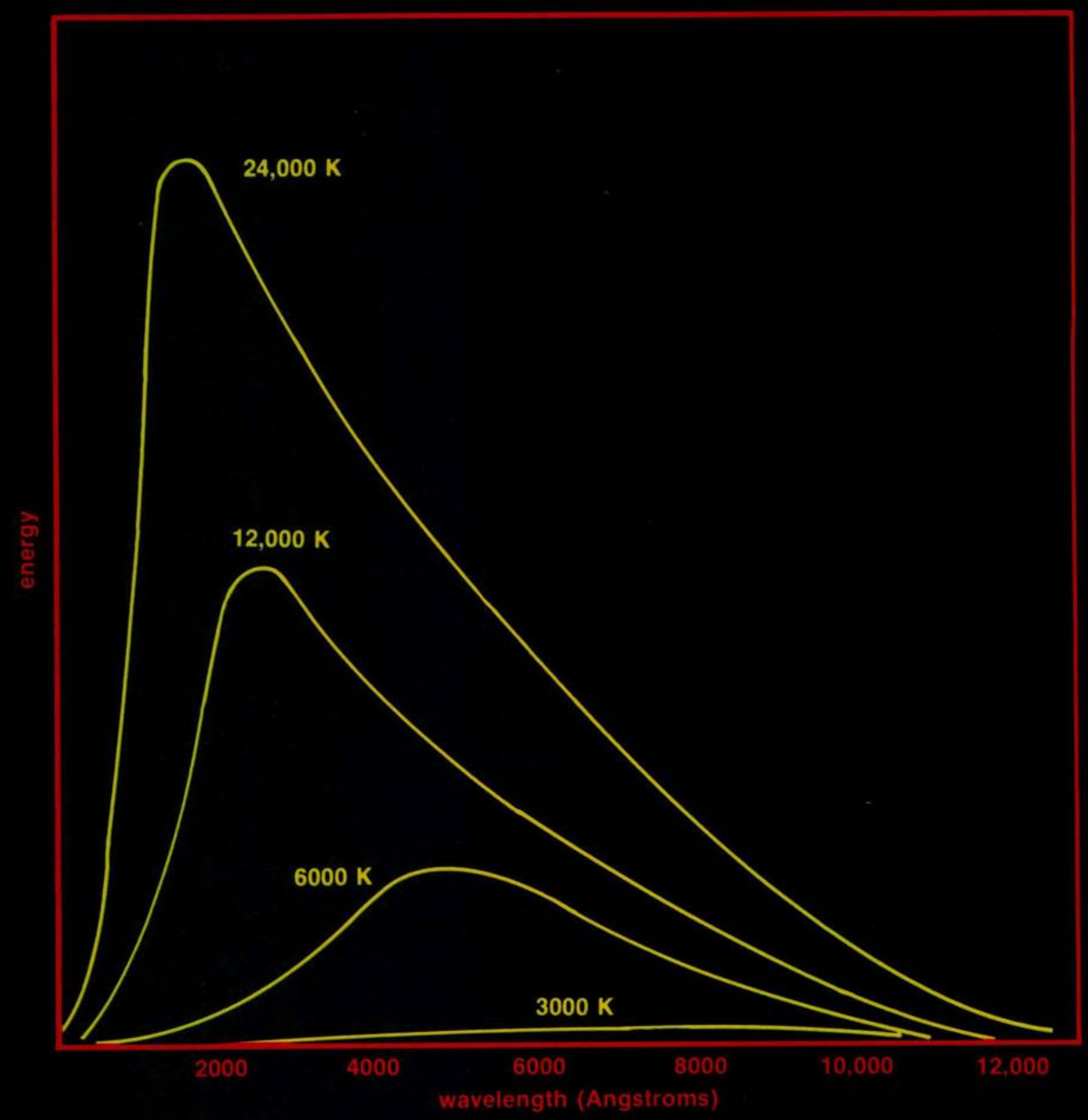
At radio wavelengths, the galaxy features a bright center flanked by large lobes of emission. (This map is 1½ times the scale of the other two on these pages.)
Artwork by Mark Paternostro after Schreier et al. in *Astrophysical Journal*, v. 251, p. 523, 1981.



In visible light, the galaxy shows a smooth oval bisected by a ragged dust lane. Photo © 1979 Anglo-Australian Telescope Board.

In the X-ray part of the spectrum, the galaxy displays several "hot spots" and a jet that connects with the radio lobes. Einstein Observatory image courtesy HCO/SAO Center for Astrophysics.





The Planck Function

Temperature	Brightest Wavelength (λ max)			Region of Spectrum	Typical Object
°K	mm	microns	A		
3°	1.0	1000	10^7	Radio	Cosmic Background
273°	0.01	10	10^5	Infrared	Earth
1000°	0.003	2.9	29,000	Infrared	Planets
3000°	0.001	1.0	10,000	Infrared	Proto-star
5600°	5×10^{-4}	0.5	5,000	Visible	Sun
10,000°	3×10^{-4}	0.3	3,000	Ultraviolet	Sirius
100,000°	3×10^{-5}	0.03	300	Ultraviolet	White Dwarf Star
1,000,000°	3×10^{-6}	0.003	30	X-ray	Neutron Star

side of the visible spectrum, we find the ultraviolet region populated with objects such as hot O and B-class stars, novae, nuclei of certain active galaxies (including Seyferts), and quasars. Also bright at ultraviolet wavelengths are the white dwarfs — tiny Earth-sized objects believed to be the final evolutionary product of low-mass stars like the Sun. These may be as numerous as all other stars put together.

Farther down the short side of the visible spectrum lie the X-ray and gamma-ray regions. One nearby source of X-rays is the solar corona, an extremely rarefied and hot (1,500,000 K) cloud of gas that surrounds the visible surface of the Sun. The corona's high temperature is probably due to compression by shock waves from the convection currents on the solar surface.

Since these short wavelengths are heavily or totally absorbed by Earth's atmosphere, astronomers couldn't see what was out there before satellite observatories were placed in orbit. They have found that some of the most intense X-ray sources are certain types of binary star systems and supernova remnants. Binary star systems can take many forms, most of which produce little activity. But when they consist of a supergiant star and a massive, unseen secondary object, the outcome can be very interesting.

If a supergiant's tenuous atmosphere extends too far, material from it may be drawn off by the powerful gravity of its companion. It will then impact with great force upon the surface of the companion or onto the spinning disk of matter — the accretion disk — that surrounds it. There the material is greatly heated and produces a flash of X-rays.

Astrophysicists now suspect that the unseen companions in these systems are probably neutron stars — small but massive objects that possess a density so enormous that a spoonful of their matter would weigh as much as the Empire State Building. An intriguing extreme case of this is the source known as Cygnus X-1. From the motion of the supergiant star, astrophysicists think that the unseen companion must be far more massive than any neutron star. The only other candidate is a black hole.

X-rays also emanate from certain globular clusters, including M-15 in Pegasus. This is quite surprising, as globular clusters are believed to be the oldest constituents of the Galaxy while X-rays are usually associated with young, hot objects. But a supermassive black hole could lie at the center of the cluster, and its mighty gravitational field could drag gas, dust, and possibly entire stars down into its hot accretion disk where X-rays are emitted. On an even larger scale, the giant elliptical galaxy M-87 in Virgo — also an X-ray source — may hide in its center a black hole with a mass of several million suns.

Supernova remnants provide yet another source of X-rays and gamma-rays. A supernova results when a massive star, having exhausted all available nuclear fuels, collapses upon itself, and triggers a gargantuan explosion in its outer layers. These layers plow into the surrounding interstellar medium at supersonic speeds, creating a shock wave that heats it up to the point where X-rays are emitted.

In addition, the remnant stellar core collapses rapidly into a tiny, spinning neutron star which itself beams X-rays from its magnetic poles. If the Earth happens to lie in the path of one of the sweeping beams, we will receive the X-rays in the form of regular pulses, each pulse occurring when a beam sweeps past Earth. These rotating neutron stars are known as pulsars. One such pulsar exists in the center of a supernova remnant in Taurus — the Crab Nebula.

Until now, we have assumed that we always see photons at their "correct" wavelength; this is an over-simplified view. The wavelength we observe depends upon the velocity of its source relative to us. If the source is moving toward us, the wave train comprising the photon will be compressed, and we will detect a photon with a shorter wavelength than if there were no relative motion between us and the source. Similarly, if the distance between us and the source is increasing, then the wave train will be stretched out and we see a longer wave.

This principle, the *Doppler effect*, is extremely important in astronomy. From the amount of the wavelength shift in a beam of starlight, astronomers can tell how fast any celestial object is moving toward or away from Earth. Some quasars are moving away so rapidly that their ultraviolet photons are Doppler-shifted down into the visible part of the spectrum!

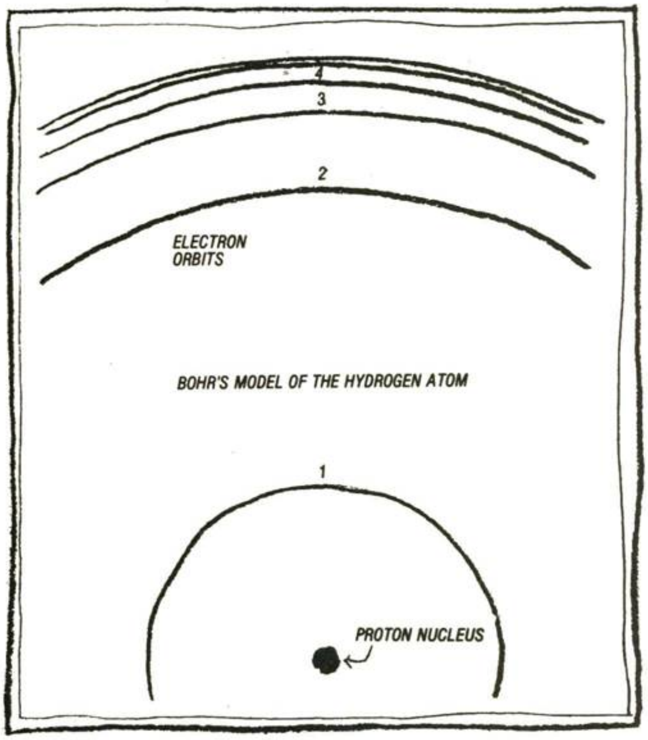
The most extreme example of Doppler-shifted radiation was detected in 1965 by Arno Penzias and Robert Wilson. They picked up radio signals which appeared to emanate equally from all parts of the sky. This emission was composed of photons radiated by the hot, dense early universe not long after the Big Bang. This radiation was originally emitted as extremely short wavelength X-ray or gamma-ray photons, but the tremendous velocity of expanding the universe shifted it all the way into the radio. (See "The Cooling Fire of Creation," ASTRONOMY, March 1980.)

By broadening our perspective to encompass the non-optical parts of the spectrum, we have deepened our view of the universe. We have not only discovered new objects but we also now see old familiar ones in new ways. We also know that all physical processes leave tell-tale clues about themselves in radiation of all wavelengths, so any astronomer who wants to know how the universe works must first understand how all kinds of electromagnetic radiation originate.

The theoretical study of electric and magnetic fields carried out by James Clerk Maxwell in the middle of the 19th centry is a good starting point. Maxwell discovered that all the properties of light and other forms of electromagnetic radiation — including its velocity and such phenomena as reflection, refraction, and diffraction — could be deduced from just four simple equations involving electric and magnetic fields. Two of these four equations are of particular importance in the production of electromagnetic radiation: a changing magnetic field produces an electric field and a changing electric field produces a magnetic field.

These two statements, simple and complementary, are easy to verify by experiment. Let's apply them to the simple hydrogen atom. In our simplified picture we use the atom envisioned by the

Danish physicist Niels Bohr, which contains a tiny negatively-charged electron orbiting a more massive positively-charged proton. The attractive electrical force between the proton and electron is balanced exactly by the centrifugal force of the electron in its orbit. According to Bohr's theory, the electron may not orbit the proton wherever it chooses, but only at certain discrete distances.



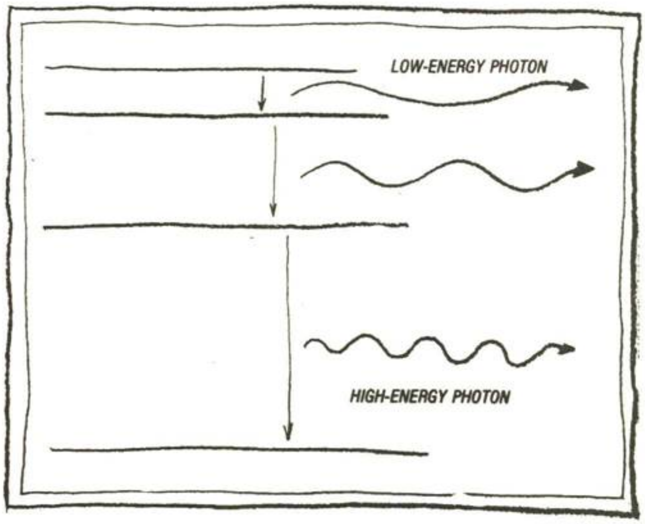
BOHR'S MODEL OF THE HYDROGEN ATOM

Suppose now that the electron fell from a high orbit to one with a smaller radius. The electric field pattern will be disturbed and will change its configuration slightly. This disturbance propagates outward from the atom as a wave, much like a "wave" moves down a long rope when you shake one end of it. In addition, since the electric field has changed, Maxwell's equations require that a magnetic field automatically appear at this instant.

This magnetic field will also propagate outward, in the same direction as the electric field disturbance, and will oscillate at right angles to it. These two fields comprise the electromagnetic wave, and radiation produced in this manner is called electric dipole radiation. The entire wave packet or train really amounts to a flash of light — a photon — of a particular wavelength and it carries off the energy the electron lost by falling inward toward the proton.

Each of the permitted electron orbits has a discrete amount of energy associated with it. The higher the orbit, the greater the energy. If the electron falls from, say, the third level from the bottom to the second, it loses an amount of energy equal to the difference in the energies of the levels. This energy is then carried away from the atom by the electromagnetic wave resulting from this transition.

The greater the distance the electron jumps, the greater the energy of the emitted photon and, hence, the shorter its wavelength. For instance, the spacing between the second and first levels is relatively large, and the photon resulting from this transition has an ultraviolet wavelength. The spacing between the third and second levels is much smaller, and a jump between these two levels yields a photon that we see as red light.



The spacing between the fourth and third levels is even smaller, and a photon emitted as a result of a transition between these two levels has an infrared wavelength. The spacings between the higher levels are smaller still, and produce correspondingly longer wavelengths in the radio spectrum. The hydrogen atom is simple; other elements, such as helium and oxygen, are not. But these more complex elements possess their own characteristic sets of energy levels just as hydrogen does.

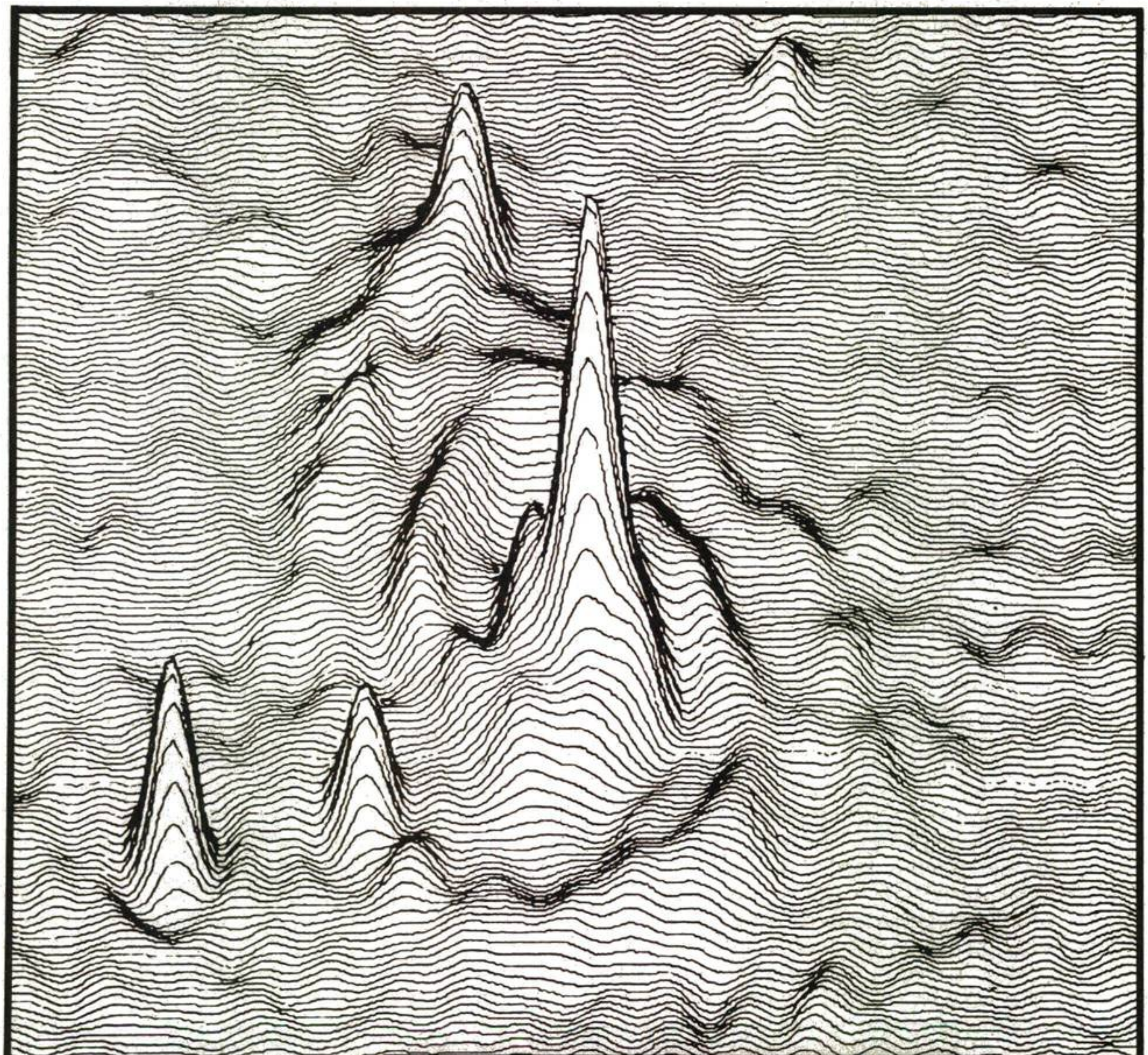
Our Milky Way Galaxy is an ideal place to study this type of radiation. Throughout its disk we find hydrogen nebulae such as the Orion and the Lagoon Nebulae, places where young, newly formed stars emit large quantities of high-energy ultraviolet photons.

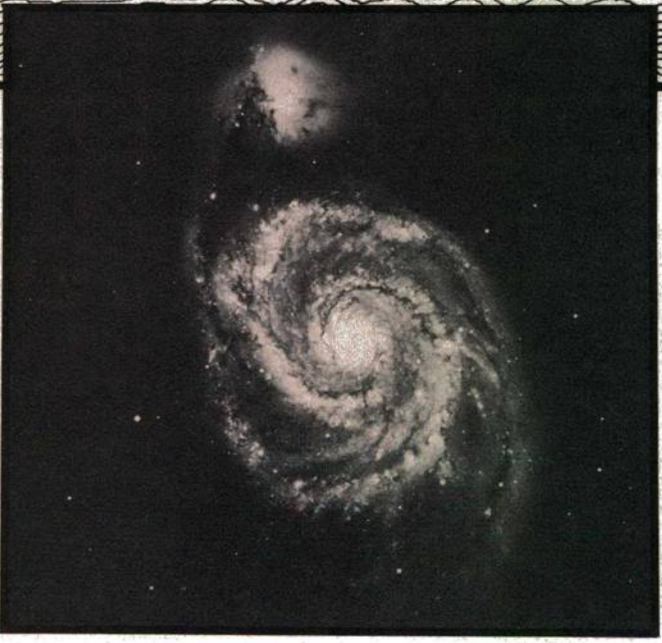
The photons emitted by these nebulae carry so much energy that when one of them hits a hydrogen atom, the atom's electron is kicked completely out of its orbit and becomes free. An electron-less atom is said to be *ionized*, and an ionized gas cloud, composed of free electrons and ions, is termed a *plasma*. Astronomers refer to regions of ionized hydrogen as *H II regions*. Regions of un-ionized hydrogen are called *H I regions*.

Electrons knocked loose from their atoms do not wander free for very long; they are soon captured by other ions. When this occurs, the electron usually cascades down through the energy levels, emitting a photon at each successive jump.

The red Hα photon is one of these, and this emission, coupled with color film's sensitivity to red light, explains why ionized gaseous nebulae look red in photographs. By contrast, our eyes' greatest sensitivity lies in the yellow-green region of the spectrum. Since these nebulae also emit some greenish light from ionized oxygen, they look green or grey-green by eye in a telescope.

Observations of emission nebulae associated





The image above was constructed from 21-cm radio observations of M-51 and clearly shows the spiral structure of the galaxy and the patterns of neutral hydrogen in it. Compare it with the visible image at right. Photo courtesy of Hale Observatories; diagram after Mathewson et al. in *Astronomy and Astrophysics, v. 17, p. 468,* 1972.

with star-forming regions in other spiral galaxies reveal that they lie in or near the spiral arms, as do most other young objects. One reason for this may be that spiral arms are generated by density waves which propagate through the interstellar medium. These might trigger star formation as they pass through the dense clouds of gas and dust which inhabit the galactic disk. (See "Do Supernovae Trigger Star Formation?", ASTRONOMY, April 1982.)

But not all emission nebulae are ruddy clouds where stars are forming; planetary nebulae — so-called because their round shapes resembled planets through early telescopes — are also quite numerous throughout the Galaxy. Astronomers think these nebulae represent a fairly advanced stage in the evolution of stars that have masses near that of our Sun. The nebula itself is a shell of gas which was shed by a faint, hot central star — usually a white dwarf — and is now ionized by the central star's fierce radiation.

In addition to a reddish color from ionized hydrogen, a planetary nebula often possesses a prominent greenish-blue glow of ionized oxygen. The Ring Nebula in Lyra (M-57) and the Dumbbell Nebula in Vulpecula (M-27) are classic examples.

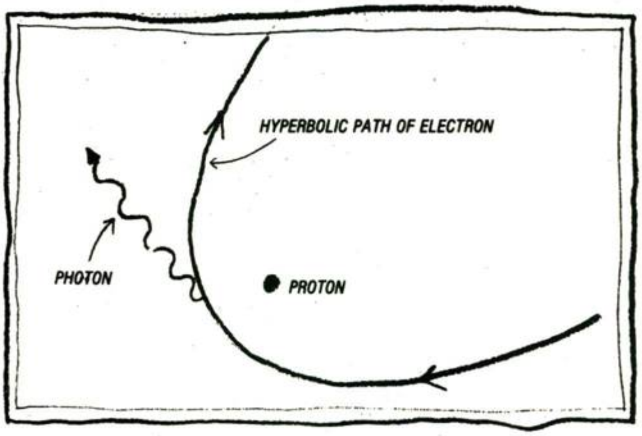
Finally, the solar chromosphere — a thin layer of gas surrounding the visible photosphere of the Sun and presumably other stars — is an emission nebula in the sense that ultraviolet radiation from the interior of the Sun — far hotter than its surface — excites and ionizes the hydrogen in the chromosphere, and makes it glow red in Hα. Normally overwhelmed by the bright glare of the photosphere, the chromosphere may be glimpsed briefly during a total eclipse of the Sun when it appears as a thin, pinkish ring of light around the black disk of the Moon.

So far we have looked at only those electrons that move from a higher energy level to a lower one — but the reverse also happens frequently. Suppose a photon of radiation hits an atom. If the energy stored in the photon is equal to the energy difference between the orbit the electron currently occupies and any higher one, then the atom will *absorb* the photon — its energy will be taken up in kicking the electron to that higher orbit. But only photons with precisely the correct energies may be absorbed. All others will be "ignored" by the atom and will pass through it unimpeded.

This highly selective process is especially pertinent to stellar astronomy. Photons with a large range of wavelengths emerge from the interior of a star and pass through layers of atoms in its outer atmosphere. Most of these photons speed through the layer unabsorbed — and a spectrograph pointed at the star will spread out the light of all the various photons and produce a continuous spectrum.

But those photons with energies corresponding to differences in energy levels of atoms at the surface of the star will be extracted from the beam and will not reach Earth. The star's otherwise continuous spectrum will contain dark absorption lines in the positions where the absorbed photons would have appeared had they not been absorbed.

So far, we have been examining what astrophysicists call *bound-bound* radiation — that is, radiation produced by an electron jumping from one orbit to another in an atom. Electrons can also produce radiation even if they are not bound to a nucleus. At temperatures of several hundred thousand K, any gas becomes partially or totally ionized and is called a *plasma*. In such a state, the electron's orbit is not closed and circular but open and hyperbolic. As an electron approaches a proton, its motion disturbs the electric field and produces a magnetic field. Sound familiar? Sure enough, by Maxwell's laws these electric and magnetic field disturbances comprise a wave which propagates outward.



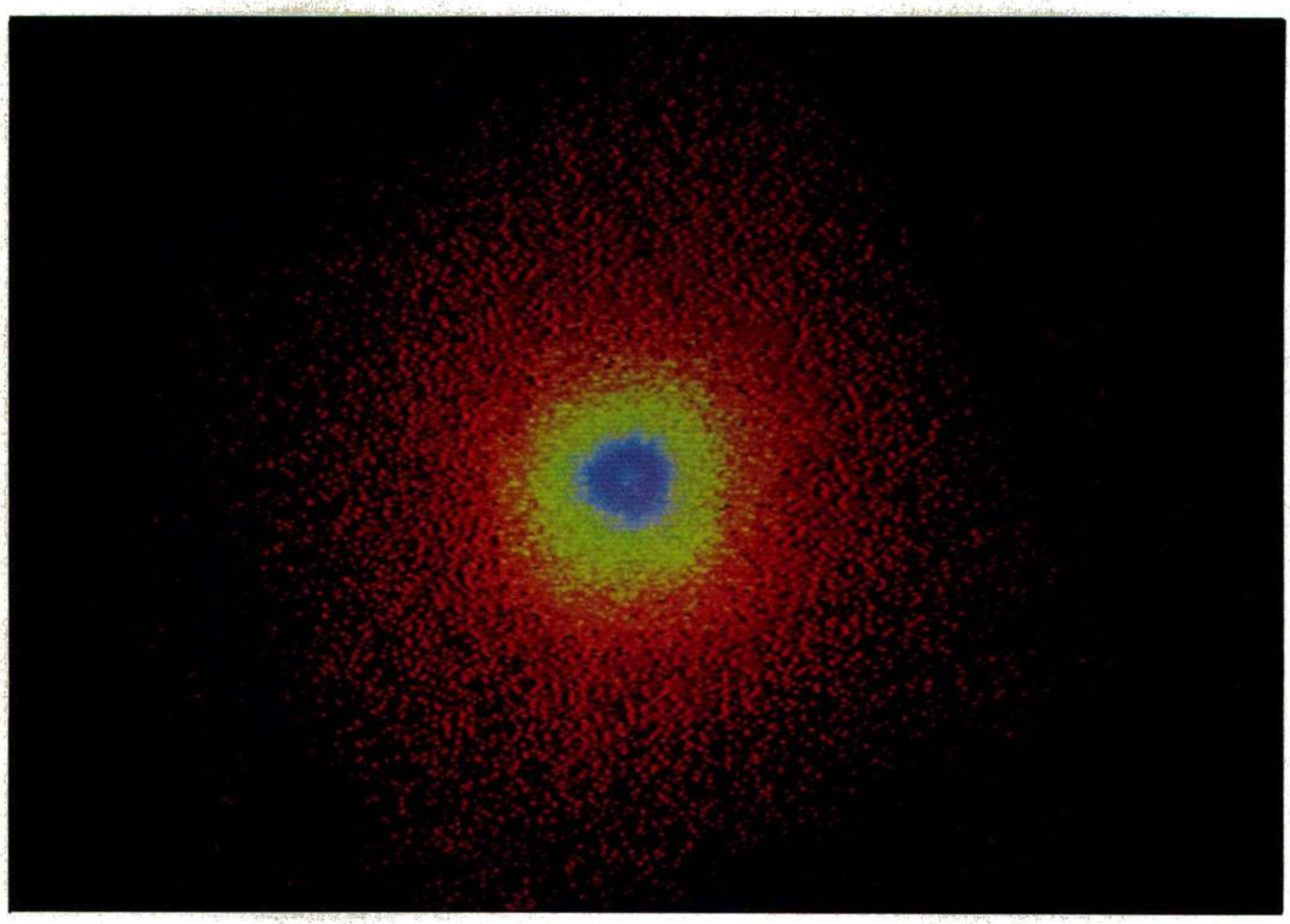
Radiation produced in this fashion is termed *free-free*, or *bremsstrahlung*, and unlike bound-bound radiation, it possesses a continuous spectrum of energies. Bremsstrahlung occurs deep inside the Sun's atmosphere where the temperature is too high for the gas to remain in atomic form. Continuous bremsstrahlung radiation passes through the cooler outer layers of the Sun where the gas has remained in atomic form and where bound-bound transitions may occur. In doing so, it produces absorption lines in an otherwise continuous spectrum.

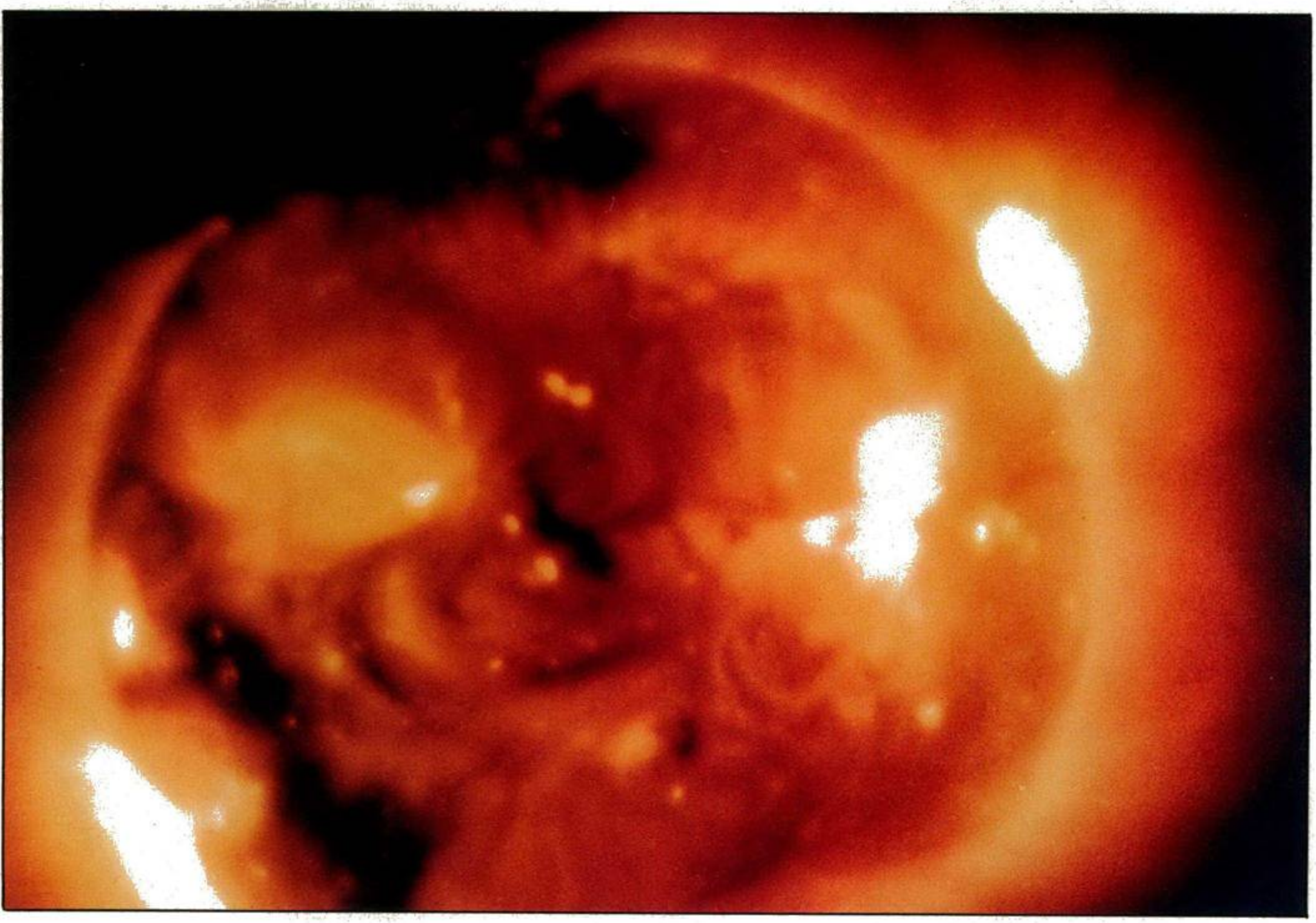
To sum this up in a simple way, a solid, liquid, or gas placed under high pressure and heated to incandescence emits a *continuous spectrum*. A tenuous, low-pressure gas heated to incandescence emits an *emission line spectrum*. And when light from a continuous source passes through a tenuous gas, *absorption lines* appear in the continuum.

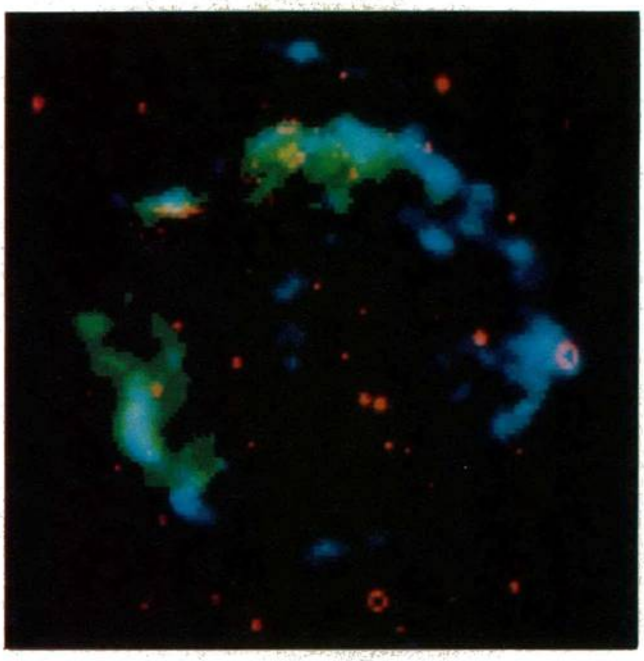
If we apply these principles to a star, we see that the hot, dense stellar interior contains incandescent gas under high pressure — and is a source of continuous radiation. The outer atmosphere of the star is a tenuous, low-pressure gas which produces emission lines if viewed alone and absorption lines if viewed in the continuous light from the interior.

So far, we've seen how an oscillating electric dipole produces electromagnetic radiation. Since there are plenty of electric dipoles around in the form of atoms, electric dipole radiation is quite common in the universe. But according to Maxwell's equations, an oscillating magnetic dipole should also yield

Above right: The hot intergalactic gas around the massive galaxy M-87 in the *Virgo cluster is a strong source of X-ray emission.* Einstein Observatory image from the HCO/SAO Center for Astrophysics. Below: the X-ray solar corona has a wispy structure. Photo from American Science and Engineering.





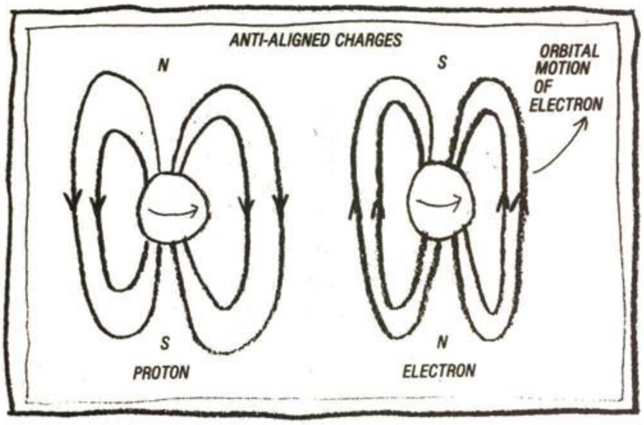


Left: In visible light, spiral galaxies such as M-31 show nuclei of old yellow stars and disks of young blue stars. Right: This composite image of the Cas-A supernova remnant shows X-ray structures in green, visible in red, and radio in blue. Images from HCO/SAO Center for Astrophysics.

electromagnetic waves. Does it?

Let's look at the hydrogen atom again, but from a different point of view. In this atom, not only does the electron orbit the proton, but each one also spins on its own axis. Since they are electrically charged, they each become a tiny electromagnet.

You may recall another grade-school science experiment: the compass inside a loop of wire. When you connected the loop to a battery, the compass needle deflected in response to a new magnetic field produced by the current flowing in the wire. The electron and proton of an atom act as if they've been subdivided into many such loops, each one carrying a current due to its rotation.



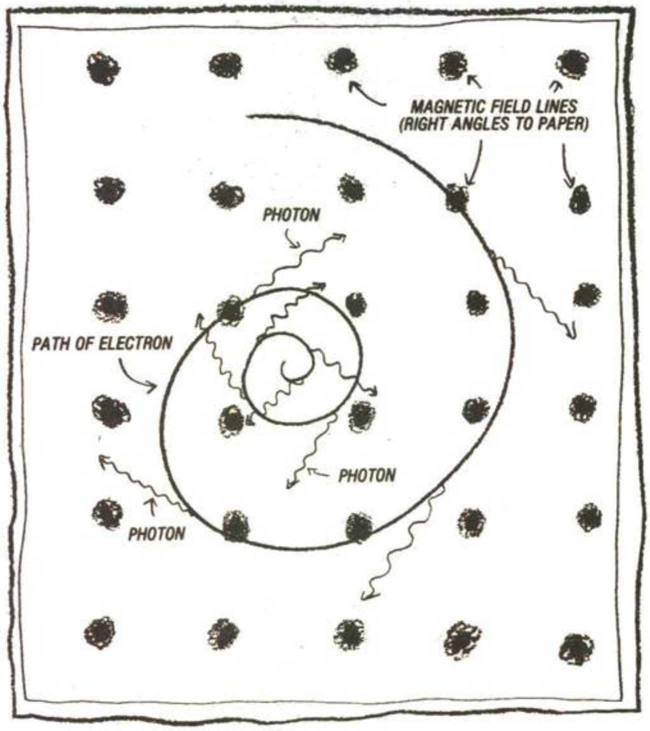
Imagine the electrons and protons as tiny bar magnets suspended freely in space. Suppose that the two magnets are anti-aligned — the north pole of one is at the same end as the south pole of the other. This configuration is stable; if we were to tap one of the magnets slightly, it would return to this equilibrium position. If we try to turn one of the magnets end-for-end, we'd find that it took energy to do so. And, supposing that we did re-align the magnets — putting north with north — we'd find it difficult to keep them like this because the poles would repel each other.

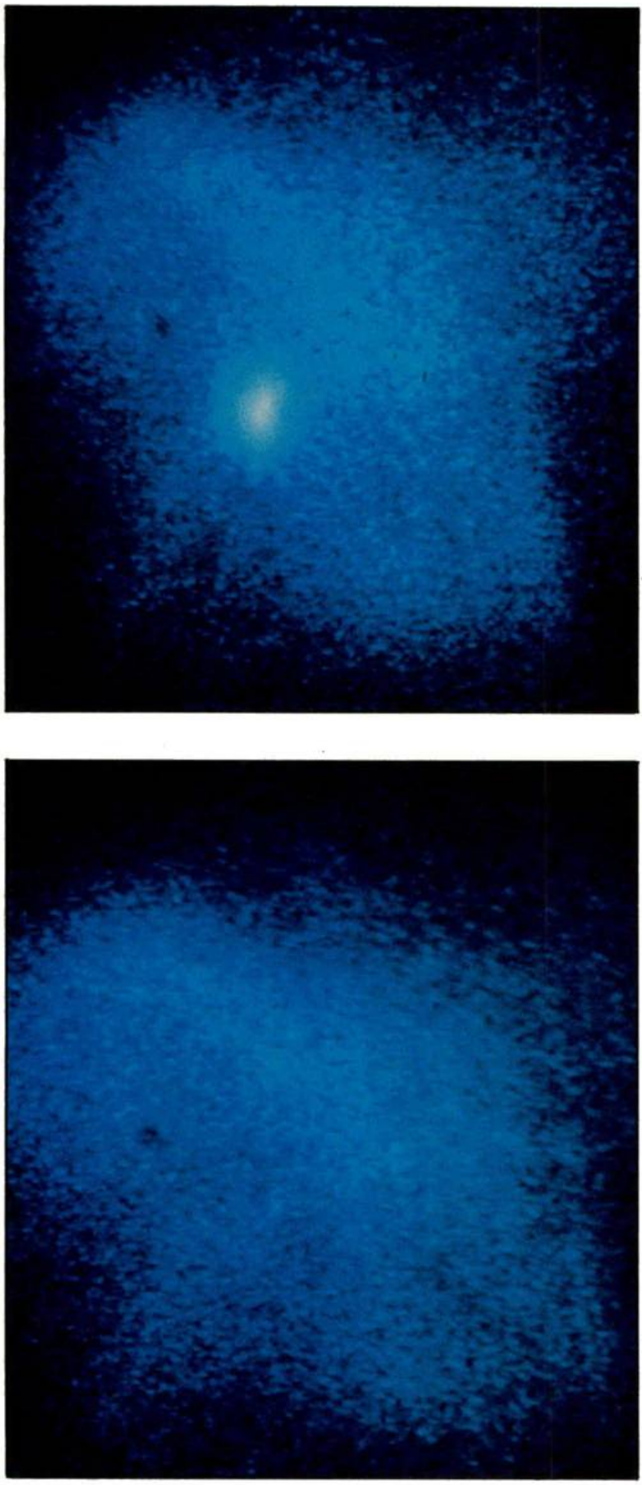
But here's the surprise: even if we left the poles aligned in the stable configuration, they wouldn't remain that way forever. Left to themselves, one of the magnets will eventually flip over. Why?

Nearly all hydrogen atoms in space are in the stable mode, with their spins anti-aligned. Occasionally, however, two atoms collide and the energy of the collision flips one of their electrons so its spin is aligned with that of its proton. The atom is then in an unstable configuration and its electron will shortly flip back to its original position. This transition causes a change in the magnetic field pattern and, in accordance with Maxwell's equations, produces an electric field that propagates outward along with the magnetic field disturbance. These two fields comprise an electromagnetic wave train with a wavelength of 21 centimeters.

Because we can detect radiation of the 21 cm wavelength with radio telescopes, we know that neutral hydrogen, or HI, clouds are present in space. Moreover, the intensity of the 21-cm radiation tells astronomers how much hydrogen lies in a particular direction, and by its Doppler shift, they may infer its velocity.

Electromagnetic radiation can also be produced by an oscillating electric dipole or an oscillating magnetic dipole. But there is yet another method of generating radiation — this time involving relativity. Suppose that an electron or any charged particle encounters a magnetic field at right angles to the magnetic lines. According to classical physics, the electron will "feel" a magnetic force that deflects it into a circular path. It will follow this path indefinitely unless it collides with other particles.





At the heart of the Crab Nebula in Taurus lies a spinning neutron star. As it spins, it sends out a beam of radiation that appears to turn on and off about 30 times per second. In these X-ray images from the Einstein Observatory, we see it on (above) and off (below). Courtesy HCO/SAO Center for Astrophysics.

But if the speed of the electron is a significant fraction of the speed of light, the electron will not maintain a fixed orbit of constant radius; instead it will spiral in toward the center. As it does so, this electron loses energy which appears in the form of electromagnetic radiation. The magnetic part of the emitted wave is parallel to the magnetic field in which the electron is immersed, and the wave travels in the same direction the electron was going at the instant it was emitted. The wavelength of the radiation depends upon the speed of the electron and the intensity of the magnetic field. Astrophysicists call this *synchrotron radiation* because it was first observed in synchroton particle accelerators in the 1940s. Another term for it is nonthermal radiation, since it is not produced in a hot object such as a star.

We find a strong natural source of synchroton radiation in the Crab Nebula, the remains of a supernova blast. We detect two remnants of the explosion — a spinning neutron star which represents the core of a once mighty star, and the surrounding nebulosity, which is laced with powerful magnetic fields. The neutron star injects rapidly moving — relativistic — electrons into the nebula and its associated magnetic field, and produces synchroton radiation at wavelengths ranging from radio to X-rays. Other objects such as quasars, active galaxies, the solar corona, and the planet Jupiter have also been found to emit appreciable amounts of synchroton radiation.

Since synchroton radiation is emitted with its magnetic component parallel to the external magnetic field, radiation received from a synchroton source will have its magnetic plane aligned along certain directions — depending upon the orientation of the external magnetic field. This effect is called *polarization* and we see it in the Crab Nebula and other synchroton sources. By passing the light from these objects through special polarizing filters, astronomers can deduce the configuration of the magnetic fields associated with the synchroton radiation. This helps them understand what the physical conditions are in the source.

Today we know that the universe is permeated not only by matter but also by energy — energy in the form of photons that have been emitted by the whole menagerie of objects inhabiting the cosmos. We also know that at least three different phenomena can produce electromagnetic radiation, and each one finds applications in astronomy and astrophysics.

Electric dipole radiation is important in the atmospheres of stars and gaseous nebulae. Magnetic dipole radiation is produced by neutral hydrogen clouds in the Milky Way and other galaxies. And finally, synchroton radiation is always associated with objects possessing strong magnetic fields — the Crab Nebula and other supernova remnants, exploding galaxies, quasars, and even Jupiter.

Now that they can examine and at least partially understand the encoded messages sent out at all wavelengths by all types of physical processes, astronomers can deduce the true nature of both nearby and remote objects in the universe. It isn't necessary to reach out and scoop up part of a star to know what it's made of, or to visit a quasar to tell how far off it is. In a very real sense, the universe comes to us — provided we know how to decipher its calling card.

Harry Augensen is an astronomer at Swarthmore College. His research interests include the central stars of planetary nebulae. Jonathan Woodbury is a graduate of Swarthmore and participates in the photographic observing program at Sproul Observatory.

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ASTRONOMY FORUM

(Science Magazines)ⁿ

Five years ago you didn't have much choice if you wanted a scientific magazine written for the layman. If you were scientifically trained, you could reap a monthly harvest of information from esoteric journals published by various societies. If you had little formal training — but could still grasp the occasional heady concept — you read *Scientific American*. But if you were unable or unwilling to translate jargon-laden treatises or plow through sometimes difficult prose, you were left only with magazines that published science fiction and pseudo-science. Not a single beacon shone in the void between the oracles and the charlatans of scientific information.

Walk into a well-stocked newsstand today, and you'll see that the problem of "No Choice" has become a problem of how to choose from so many. You can find perhaps a half-dozen magazines on the shelf that have taken the language of scientists and translated it for the reader with no scientific background. For two or three dollars, the following magazines will help bridge the gap between you and the forefront of science.

Discover

In July 1981, Time Inc.'s mitosis created *Discover*, the publishing giant's entry into the science-for-the-masses movement. As you'd expect, the new magazine resembles *Time* in its format and attitude — heavily departmentalized and occasionally glib. Once you open *Discover* you're taken over by the same liveliness that has made *Time* so popular — and you hardly turn a page without being drawn in by a splash of color from a photo or a neatly explicative graphic.

Discover is, indeed, what it claims to be — "The Newsmagazine of Science." Written for the same people who pick up *Time* at the end of the week to see what happened while they weren't reading the newspapers, it delivers a monthly summary of the world of science. You won't find much depth or detail in *Discover*, but plenty of people must want their science on the run — the magazine boasted 750,000 subscribers at last count.

Discover manages to keep a historical perspective at the same time it focuses on the science of now. In a recent issue, a story on NASA's latest experimental packages for the Space Shuttle is sandwiched between a capsule history of a famous 19th century scientist's accomplishments and a heavily illustrated review of a book on a forgotten genius. And because of its parentage, *Discover* can cover the scientific news of the day that doubles as the history of the day like no other magazine. Witness its four-color/courtroom artist-illustrated/you-were-there-in-Arkansas coverage of the Neo-Scopes Trial. Bannered across half of a two-page opening spread, the article's title proclaimed: JUDGMENT DAY FOR CREATIONISM.

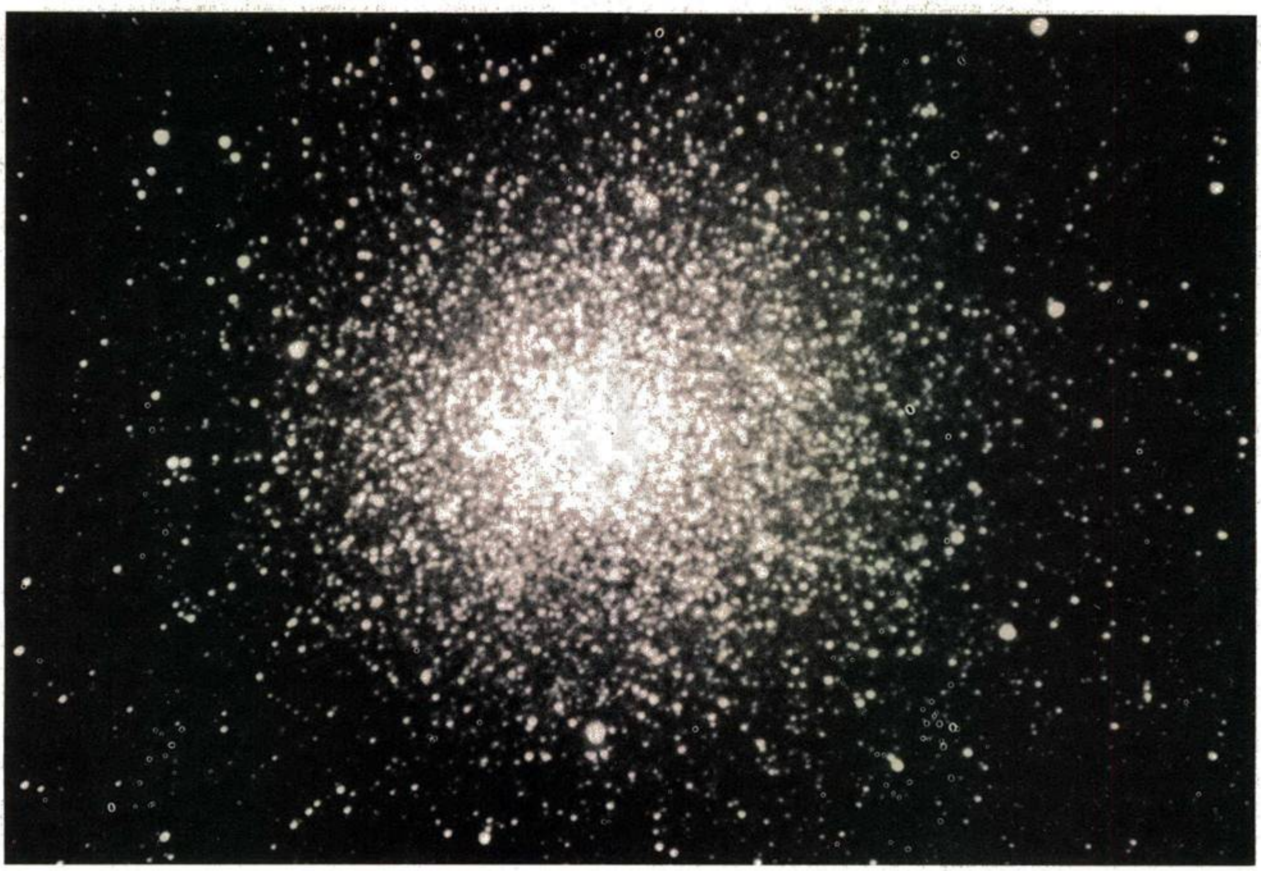
If a magazine can extract science news from the morass of statistics and equations that often swallows it up, then convince its readers that those men in white lab coats who are hunched over petri dishes or hypnotized by a computer display terminal actually have an effect on their lives, it has a better chance of interesting the general public in science.

Discover tapped this stream of self-interest recently with a story on the Search for Extraterrestrial Intelligence (SETI) program. Despite its highly technical methods and the cold array of radio telescopes it uses in its search, SETI has an inherent appeal to the masses — the romance and controversy of life on other planets. Since the first writer described the first little green man, the possibility that we have siblings in the universe has intrigued the sentient among us.

Science Digest

Remember the country fair freakshows where a sleazy barker stood in front of larger than life paintings of The Two-Headed Lady and Frog Baby and begged you to come in and look? And remember when you finally spent the 25 cents admission and went in? Despite what the barker promised, you didn't see a woman with two heads: only an unfortunate girl with a large growth on her neck. And you didn't see a half-frog, half-human baby: only a small, bored man with atrophied legs reading a book. If you remember this scenario from America's past, you already have a 3-D image of the cover of *Science Digest* — and a good idea of how much it differs from the magazine's contents.

The most blatant non-delivering



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This remarkable photograph of Omega Centauri was taken at Apache Pass, Arizona, by Hubert Entrop. He writes us "The wind blew from the west in strong gusts but I located in a low north-south arroyo beside a large bush to protect the scope. The atmosphere was miserably rough but in spite of it, it's a good Omega Centauri. Imagine what it would be like if we could have it straight overhead instead of so low on the horizon. Exposure 1 hour 30 minutes on Tri-X."

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cover blurb I've seen on a *Science Digest* (and there are many) simply read: "Sex in Space — Actual Experiments." Those five words opened a lot of *Science Digests* — and probably sold quite a few. But once you opened the magazine, it was hard to reconcile the cover blurb with the story — 1½ columns about the completely untitillating antics of frog embryos in a weightless environment. The item was buried in *Science Digest*'s Mind and Body department on page 98.

Another classic come on was "Human Fireballs — People who Burst into Flames." This story delivered what the hook promised — unfortunately for the queasy. It was a grisly history of Spontaneous Human Combustion (SHC) — a phenomenon which supposedly causes its victims to ignite like the head of a match. "Fireballs" was fascinating reading, but it was also largely undocumented except for a photograph that the *National Enquirer* would have given its libel defense budget for, and a few references to SHC incidents in fiction.

In all fairness, *Science Digest* credibly reports some science stories. The same issue that hyped frogsex and the self-igniters explored the properties of the metal Nitinol — a substance with a "memory" that allows it to return, when it is heated, to its original shape — from any configuration it's bent into. The magazine outlined intriguing possibilities for the use of Nitinol in low-cost energy production.

Science Digest's 530,000 subscribers are also offered articles by mainstream scientists and science writers including Robert Jastrow and Isaac Asimov. But I still open the magazine because of its shameless hooklines more often than I do for its "hard" science. Right now a cover line is inviting me to learn how to Summon the Creative Fire from my Unconscious Mind. More SHC, perhaps?

Science 82

Science 82, the most recent of *Science 80*'s ascendant offspring, charts an editorial course somewhere between the hucksterism of *Science Digest* and the glib yet informative style of *Discover*. The magazine has a flair for the melodramatic without letting it handicap a story line or drive off the reader who wants "just the facts, please."

In the April 1981 issue of *Science 81* — since grown to *82* — staff writer Michael Gold plots out a detective story with the pacing and style to satisfy most mystery readers. But along the way, the path is scattered with bits of scientific information on cancer research instead of murder weapons and inconveniently appearing corpses. The author traces the *HeLa* cancer cells of Henrietta Lacks on a path to practically every cancer lab in the world and outlines how they have set back cancer studies by overtaking many other cells — unbeknownst to the scientists doing the research.

> *Science 82 displays a flair for the melodramatic without driving off the reader who wants "just the facts, please."*

In a more recent issue, *Science 82* offerings ranged from the mix of anthropology and mysticism presented in a story on a 14,000 year-old cave in Spain that may have been man's first religious shrine to a report on a nuclear powered aircraft — not aircraft carrier — that was proposed and studied at a cost of 1 billion dollars, then scrapped as impractical.

The March issue of *Science 82* capitalizes on "calorie phobia" with a story on the physiology of fat. The cover features a photo of a leotarded woman measuring her waist. With the demand for diet books operating full throttle, this issue had to be a winner for *Science 82*. Think of the percentage of men and women in this country who are overweight, or think they are overweight; then consider (by visiting the self-help section of any bookstore) how obsessed we are with looking great and loving ourselves — both our bodies and our minds.

The story was useful; it debunked a few myths about diet and explained just how unhealthy and unnecessary it may be to strive for anorexic chic. But the key to the success of the story was that it touched a current nerve in the reading public — a nerve that runs through the fatty tissues in most of our bodies. Once again, the application of science to our personal concerns bridged the gap between science and the citizen.

The editors at *Science 82* — and the American Association for the

À la Carte

No matter what magazines you read, it's a safe bet that you page directly to your favorite sections, see what they offer, and then go back and read the rest. Here are the sections that I find myself turning to in the science magazines:

Scientific American: 50 and 100 Years Ago. *Sci Am* is, of course, the only science magazine old enough to give you a perspective like this. Open to this section in any issue and you'll see who and what was at the forefront of science a century or a half century ago — an interesting way to get a thumbnail sketch of how far science has come since those days. Did you know that the first food and drug purity laws were being drafted in 1882?

Discover's Skeptical Eye is what every contemporary science magazine needs to keep on the world — especially when it's so easy to trap readers with invocations of the bizarre, and quasi-science. *Discover* gets the best of both worlds out of this section: It can present a popular myth to satisfy its proponents (anything in print adds credibility) and it can debunk those theories in the same section. But Skeptical Eye is more than an attention getting device for *Discover*. It presents a different point of view on various myths — including that of budget-cutter as unquestioned hero. In a recent issue, it examined U.S. Senator William Proxmire of Wisconsin who has burdened the world of scientific research with more of his Golden Fleece awards than it deserves.

Science Digest's Letters column involves its readers — not just by answering questions, but by asking readers to do things. One of the more reasonable requests was for letters from readers who wanted more astronomy articles. At the other end of the spectrum, an editor's note requested letters from its readers who have seen record-length snakes. One reader wrote that he was in the process of searching for a record snake and would keep the editors posted. Now *that's* reader loyalty.

For those who like their science sweetened with a bit of down-home folksiness, Jake's Page in *Science 82* might be just the remedy. Jake Page, who writes the namesake column, may drop too many "boyish grin" colloquialisms into a story for some readers, but he makes his points. And he makes interesting aspects of science and human behavior easier to understand.

OMNI's Games section is a refreshing collection of puzzles ranging from the visual and the conceptual to the linguistic. It would be hard to find someone curious enough to read an issue of *OMNI* who could not also find something in Games that would challenge and delight him. A recent section on words offered an educational and entertaining look at the building blocks we use for communication — with insights into origins and changes in meaning through the years.

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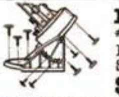

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Advancement of Science which publishes the magazine — seem to have a comfortable grasp of what their 700,000 subscribers want. Mystery — as it relates to science — technology, a bit of history, and a generous dose of human interest are combined in each issue and made relevant to our everyday lives.

OMNI

OMNI is *sui generis.* A hybrid, it combines speculative fiction with speculative articles about scientific advances written by Big Name Authors and illustrated by Big Name Artists. *OMNI* doesn't shrink from delving into the weird side of science. It doesn't fade away on the fiction side either, publishing such luminaries as Ben Bova (editorial director and frequent contributor) and Harlan Ellison. But the combination of science and fiction makes an uneasy marriage — something akin to finding Damon Runyon stories in *Sports Illustrated*, or a stuffy NASA press release in *Weird Fantasy*.

Articles in *OMNI* range from pictorials by space artists to excited treatises on advances in genetic engineering, but the magazine's sometimes overworked enthusiasm gives it an editorial flavor similar to that of *Science Digest*. A rundown of the contents page of *OMNI* will give you an idea of the scope and attitude of articles it publishes. Through departments titled Earth, Life, Space, and Mind (perhaps *OMNI* has redefined the four elements) and the ubiquitous Books and Film, *OMNI* investigates and wholeheartedly endorses life at the contemporary/future border.

OMNI combines speculative fiction with speculative articles about scientific advances in the contemporary world.

An article in a recent *OMNI* collects detailed descriptions from a group of people who had out-of-body experiences while they were near death, or clinically dead. *OMNI*'s choice of editorial material often combines scientific and psychological research with overtones of the mystical and occult. The mixture is a guarantee for high readership, capturing both the scientifically inclined and the spiritually motivated reader — and those who are accepting or skeptical of both sides.

OMNI has obviously struck a chord that resonates with the reading public. Founded by Bob Guccione of the *Penthouse* empire in 1978, the magazine has grown to a circulation of more than 820,000 and enjoys heavy newsstand sales. Are *OMNI* readers science fiction fans reaching out for reality, or empiricists escaping the world of fact? It's difficult to tell, but I am certain the magazine's marketers would say yes to both.

The people who decide and debate *OMNI*'s editorial content may have discovered the key to science publishing success. If you target the people with interest in science — and offer them reasonable explanations of what is going on in a world of rapid change — and then add science fiction by well-known authors and a touch of the occult to capture that huge market of speculative science readers, you have the eyes and minds of a large segment of the reading public focusing on your magazine. And when you couple this mass-appeal format with a financially healthy parent corporation that has muscle at newsstands throughout the world . . . . You know the rest.

Scientific American

Scientific American published its first issue in 1845. James K. Polk was President of the U.S. — its fifteenth; Mark Twain was 10 years old; and William Parsons, 3rd Earl of Rosse, had just completed his 58-foot-long reflecting telescope at Birr Castle, his Irish home. It's obvious that someone has been doing something right for a very long time.

In its 137 years, *Scientific American* has presented the advancements of science to those who can penetrate its sometimes difficult prose and grasp the often difficult concepts it presents. If you have an aptitude for the sciences, and don't mind spare — but always clear — graphics and a monotonous post-and-lintel layout, you are probably already one of *Scientific American*'s 720,000 subscribers.

Despite its stodgy appearance, *Sci Am* is not narrowly directed or static. Its science ranges from articles that intrigue the naturalist to those that satisfy the most avid computer-processing aficionado. The book also studies the "science" of economics with enough flow charts and graphics to widen the eyes of an aspiring John Maynard Keynes or Adam Smith. *Scientific American* covers all that is science and engineering from biology to acoustics to laser weaponry.

Scientific American's prose comes close to being all things to all readers. Scientists can read any article without thinking it beneath their intellectual dignity; non-scientists can read the same article and understand at least the broad concepts laid out in the beginning paragraphs. And although the magazine tackles subjects as complex as how fish see colors and how DNA molecules repair themselves, it also presents science that is already familiar to the generally educated public.

In the Amateur Scientist, and Science and the Citizen, for example, *Sci Am* helps explain how the laws of science affect our daily lives. This provides a necessary bridge from the lab to the hearth — one that all scientists should be building. A recent Amateur Scientist explained the optics of pinhole cameras — simple devices familiar to many of us since childhood. Another explained — through the architecture of a sand castle — the physical principles which cause wet sand particles to stick to each other. Science and the Citizen has investigated subjects as diverse as the U.S. census and new uses and planting techniques for sunflower seeds. *Sci Am*'s book section also presents an array of topics — from colonial American cartography to astronomy — that scientist and layperson alike can enjoy.

Scientific American published its first issue in 1845, the same year that William Parsons completed his 72-inch reflecting telescope.

The major reason for *Scientific American*'s venerable state is probably its acceptance by both the scientific and the lay communities. If the magazine could be read only by the finely-tuned scientist, it wouldn't have a very broad market to capture. But *Sci Am* can be read by most people who are willing to put some effort into understanding a complex world that affects them — to varying degrees — every day.

We can be thankful we live in an era when publishers can make a profit from humanizing and disseminating scientific information. Otherwise we'd be back to the "No Choice" problem. As it stands today, you have a wide range of choices, and you can read the magazines that wrap science in the package that appeals to you the most: You can have your science reported like today's news. You can have it hyped beyond its already interesting proportions. You can have it as an optimistic endorsement of life in our modern world. Or you can have it straight-from-the-hip in the language of the no-nonsense empiricist. The important thing is that you can have it; it's yours for the asking.

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eye on the sky

planets bejewel june sky

by Fred Schaaf

the wanderers

During June, **Jupiter** and **Saturn** hesitate and then head eastward against the constellations' seasonal progression. But while these cumbersome gas giants pause, Mars accelerates and approaches them, closing the ranks of splendor in the southwest sky.

Mars almost catches Saturn by the end of June, and during the months ahead it will overtake one planet after another: Saturn in July, Jupiter in August, Uranus in September, and Neptune in October. The red planet is nearly a zero-magnitude object in early June, but fades a third of a magnitude as the Earth leaves it behind in our orbital race.

Saturn resumes direct (eastward) motion on June 19, and spends the whole month almost motionless just a few degrees northwest of 4th magnitude Theta (θ) Virginis. The ringed planet lies about nine degrees northwest of Spica, and shines just a bit brighter than that first magnitude star.

Jupiter, fading from magnitude -2, also appears stationary all this month, but it will start back eastward on the 28th. Since Jupiter is nearly as far northeast of Spica as Saturn is northwest, these two planets seem to keep a patient guard on Spica all month. The trio's fixed pattern of beauty and brightness is enhanced by the approach of Mars.

If you are in dark skies, try spotting **Uranus** with your naked eye. It is riding the head of the Scorpion, just a couple of degrees southwest of Beta (β) Scorpii.

If you want to find an even more distant planet, use binoculars and the directions in The Backyard Astronomer to locate 7th magnitude **Neptune**. This planet is at opposition on June 17. During the month, it retrogrades from Sagittarius into Ophiuchus where it will lie until late this year. In about 18 months, Neptune will be in conjunction with Venus and Jupiter while all three pass right by M-21 and M-20, the Trifid Nebula.

The outermost gas giants are dim, but two brilliant worlds shine in the morning sky. **Venus** gleams at magnitude -3.5, and rises just after the start of morning twilight at 40° N. latitude. But 1982 is not a good year for northern hemisphere observations of Venus. The conjunction of Venus with the Sun in January shot the planet up into the morning sky for its greatest elongation. Unfortunately, this was at the same time the angle of the ecliptic to the horizon was very shallow. This left the planet low on the horizon. As summer progresses, Venus will hold its own in the morning twilight, but it will not be favorably placed until next year.

Mercury begins the month at inferior conjunction, but attains a greatest elongation of 22° on June 26, when it is favorably placed. The best time to observe Mercury is the week before greatest elongation; during that period Mercury is near the star Aldebaran. A conjunction occurs some hours before the two rise over North America on the 23rd, with Mercury passing just 1° 41′ north of the star. The objects are similar in brightness, and you'll be able to compare their color — binoculars will help.

The last time Mercury was in the morning sky — February and March — it completed the majestic bridge of eight planets and four major asteroids that spanned the south in the pre-dawn hour. When Mercury rises before the solsticing Sun in June, the outer planets, except for Neptune, have long since set.

Although this array of planets is lost, the most spectacular event of the year is just around the corner. Watch the **June Moon** accompany the Virgo group of planets at month's start, become Full on the 6th, and settle between Venus and the Mercury-Aldebaran duo on the 19th. The Moon will partially eclipse the Sun for South Africa just hours before summer solstice on the June 21. During this whole progression — and again when the Moon is passing the planets in Virgo at month's end — watch the Moon not only with appreciation, but with anticipation of a singular lunar event.

On the morning of July 6 (and eve of July 5 for western observers), the United States will get a chance to see the Moon totally eclipsed for just about the longest duration possible — 106 minutes! Make your observing plans now for that big night.

the starry sky

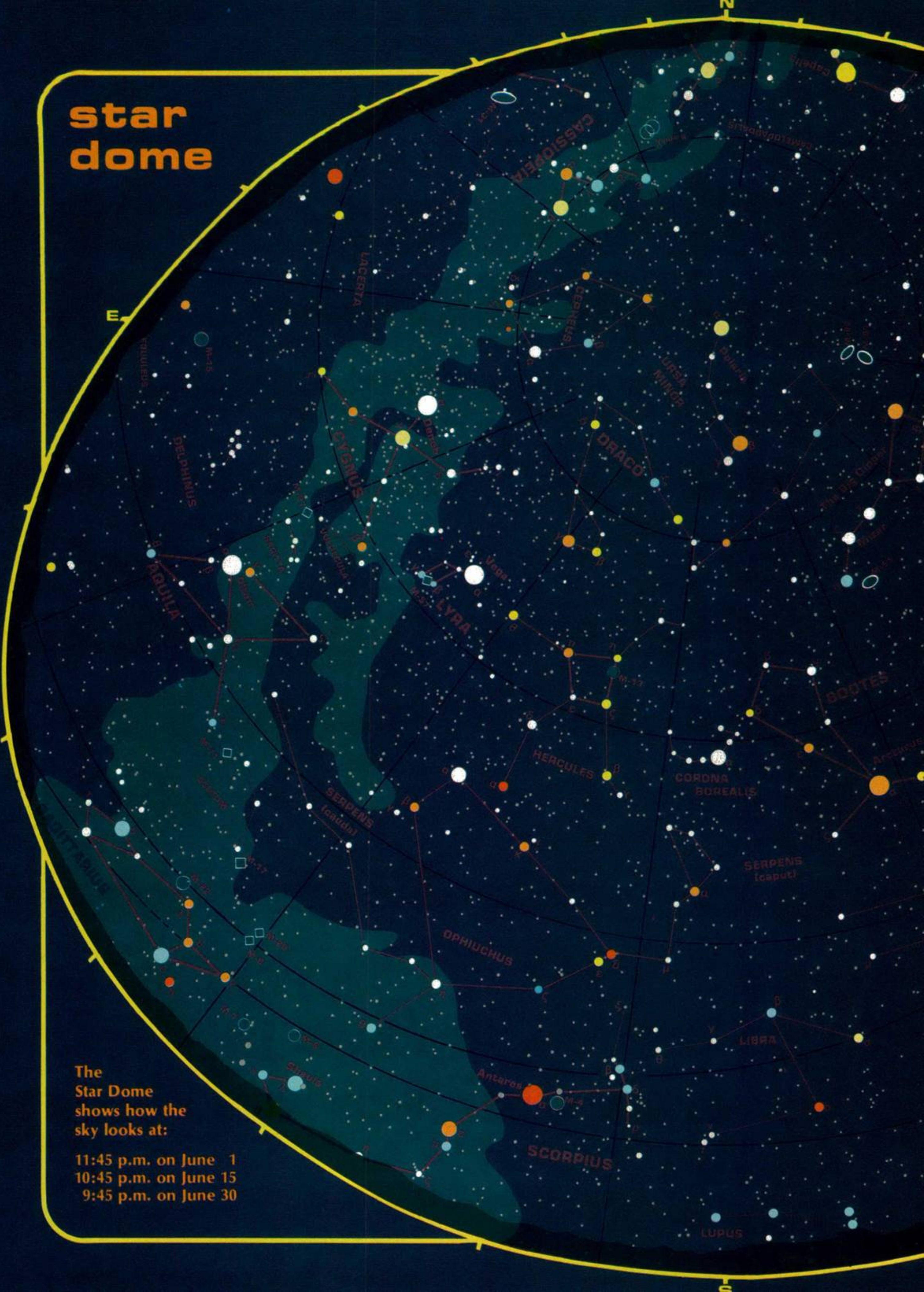
Capping June evenings is **Corona Borealis**, the northern crown. The six prominent stars of the pattern form a nearly perfect semi-circle which represents the coronal wreath. Corona Borealis has its special ornament, the bright 2nd magnitude star, **Gemma** or Alphecca. But the constellation is especially noted for its variable stars. One of its truly extraordinary objects is **R Coronae Borealis**.

You can find this star with binoculars; it's the only 6th magnitude star in the eastern part of the "cup" of Corona's pattern, right beside a 7.2 magnitude star. But R suffers a remarkable fading once every few years. Its drop, described as a "reverse nova," can reduce it to 15th magnitude. This peculiar star usually takes only a matter of months to return to its usual brightness, but it is so irregular that we can make no precise prediction of its behavior.

The Northern Crown is set between the shoulders of two giant constellation figures. To the west is

The northern lights shimmer in myriad shapes and striking colors. On February 13, Brian McNair captured this auroral display on ASA 100 film with a 35mm camera and a 50mm f/2.8 lens.

star dome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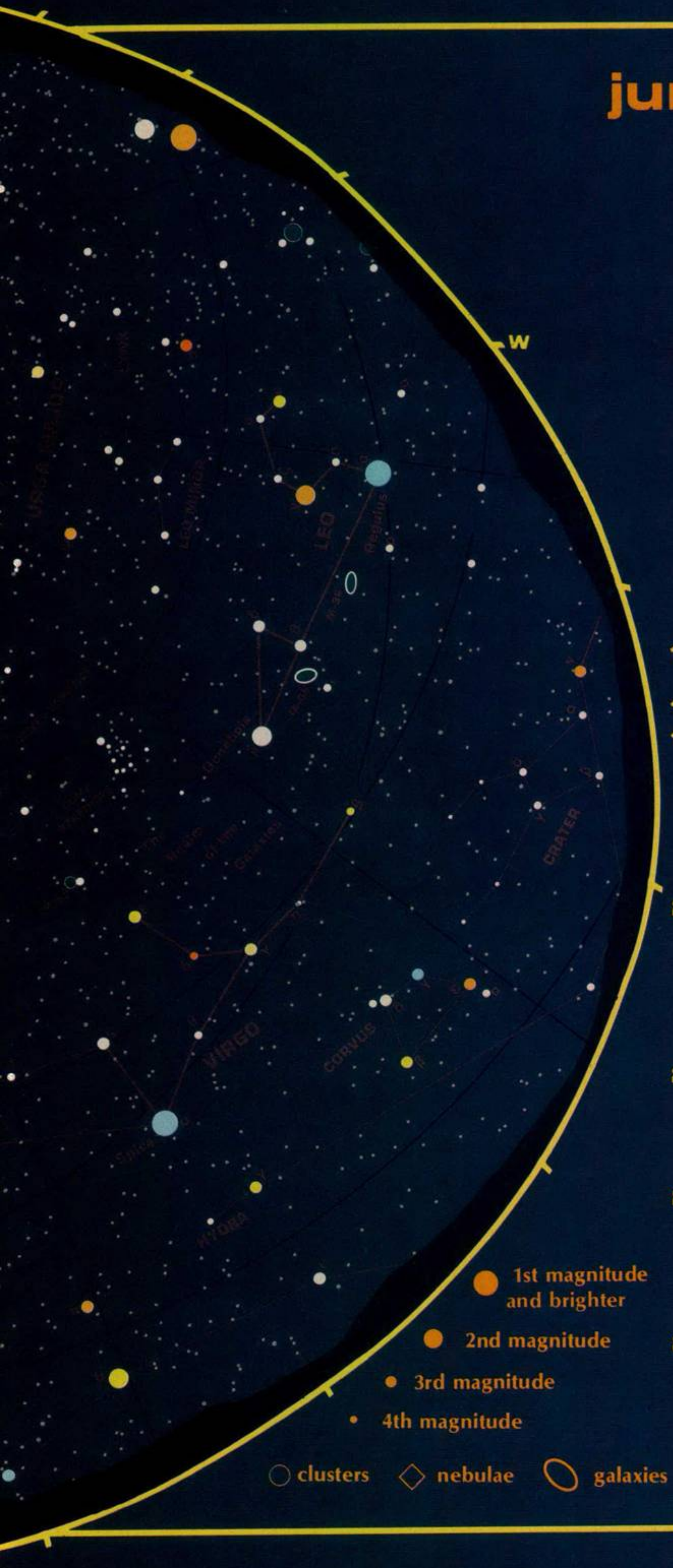
The Big Dipper
Mizar
SAGITTA
VULPECULA
Vega
LYRA
M-57
AQUILA
Altair
M-13
BOOTES
HERCULES
CORONA BOREALIS
Arcturus
SCUTUM
SERPENS (cauda)
SAGITTARIUS
SERPENS (caput)
OPHIUCHUS
LIBRA
Shaula
Antares
M-4
SCORPIUS
LUPUS

The Star Dome shows how the sky looks at:

11:45 p.m. on June 1
10:45 p.m. on June 15
9:45 p.m. on June 30


W
URSA MAJOR
LEO MINOR
LEO
Regulus
Coma Berenices
The Realm of the Galaxies
CRATER
VIRGO
CORVUS
Spica
HYDRA
● 1st magnitude and brighter
● 2nd magnitude
• 3rd magnitude
• 4th magnitude
○ clusters
◇ nebulae
galaxies

june sky almanac

1st Mercury is at inferior conjunction: it will pass between the Earth and Sun, and change from the evening sky to the morning. You'll see it low in the east-northeast just before sunrise in about 2 weeks.

2nd Jupiter lies a few degrees below the Moon tonight.

4th Mercury is at aphelion — its farthest distance from the Sun.

6th The Moon is Full at 11:59 a.m. EDT.

7th The Moon is at its greatest distance from Earth (apogee) tonight: 252,369 miles.

14th Last Quarter Moon is at 2:06 p.m. EDT.

17th Neptune is at opposition.

19th In the eastern sky this morning, you can see Venus with a thin crescent Moon to its lower left. Mercury and the first magnitude star Aldebaran appear very close to the horizon.

21st The Moon is New at 7:52 a.m. EDT; shortly thereafter, it is at its closest to Earth (perigee): 222,185 miles. Also today: the Sun reaches the solstice at 1:23 p.m. EDT, and northern hemisphere summer begins.

23rd Mercury will pass less than 2° north of Aldebaran today. Look for the two very low in the east-northeast just before sunrise.

26th Mercury is at greatest elongation west of the Sun, but it will be easier to spot in about a week. Look for the planet low in the east-northeastern sky about 45 minutes before sunrise.

28th The Moon is at First Quarter at 1:56 a.m. EDT.

Bootes the herdsman, featuring **Arcturus**, brightest star of spring, brightest star of the north celestial hemisphere, and brightest orange star in the sky. But is orange too optimistic a description? Go out and judge the distinctive tint of this old gypsy star for yourself. Be sure to use this month's rare opportunity to compare the color of Arcturus with Mars while the two lie in the same region of the sky and shine at a similar magnitude.

To the east of the Northern Crown is the huge form of the legendary **Hercules**, harboring the great globular cluster **M-13**.

In dark skies, you can glimpse M-13 with your naked eye. It is an intriguing patch of radiance in binoculars. Even a small telescope begins to show it as an awesome ball of star-mist, dusting out into glorious stellar jewel-grist. Summer is the best season for globular clusters, and M-13 is first on many observing lists. Although it may be no more majestic than M-22 in Sagittarius, its prominent position makes it memorable.

M-13 lies on the west side of the **Keystone** asterism that forms the lower trunk of Hercules. But the Keystone is neither bright nor conspicuous. To find it, trace a line from Corona Borealis (or Arcturus) to the brilliant blue star climbing high in the east on June evenings. That star is **Vega**, located in the miniature constellation **Lyra** the lyre. Sweep toward it and it will lead you eastward to the other glories of the rising Milky Way — particularly the stars **Deneb** and **Altair**.

You don't need a lot of fancy gear to produce good astrophotos — especially if the object you're shooting is bright. Short exposures with stationary cameras usually work well. For this shot of the young crescent Moon, John Asztalos used a 35mm camera and a 135mm f/2.8 lens. A 3-second exposure on ASA 400 film recorded both the lovely sunset colors and the Earth-lit portion of the disk.

On the meridian on these June nights, we can find at least parts of two different coiling serpents. One is the north circumpolar **Draco** the dragon. The rear section of his long body intrudes between the two **Dippers** and makes a kind of looping arch around the bowl of the Little Dipper, which is highest on June evenings.

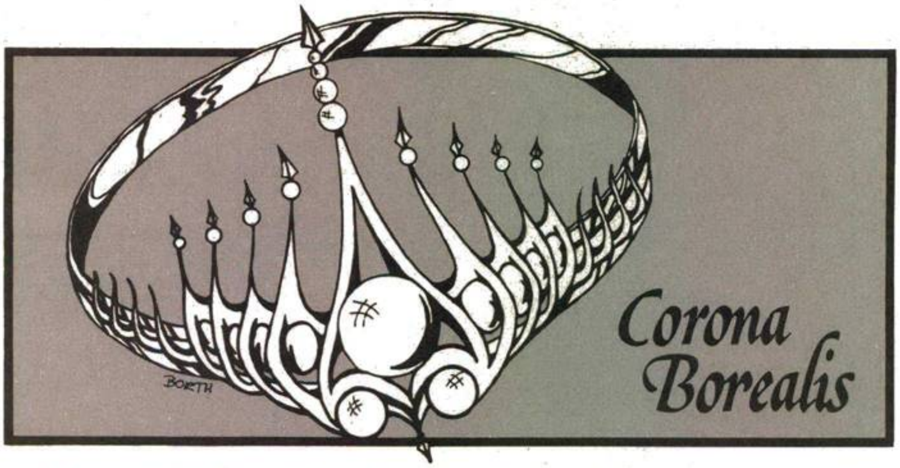
This month is a good time to survey the pole stars of past ages. The ancient Greeks used the two bright stars in the Little Dipper's bowl; they are still sometimes called the Guardians of the Pole. About midway between those guardians and the Mizar-Alcor pair in the Big Dipper's handle is another ancient pole star, Thuban, now doomed to thousands of years of obscurity as a third magnitude object in the tail of Draco. The tail of Draco points roughly towards two fascinating galaxies which look good even in small telescopes. M-81 and M-82 lie just over the border in Ursa Major.

South of Corona Borealis is the head of another serpent which reaches the meridian first. This faint little head belongs to **Serpens**, whose entire front portion — the head and neck west from Ophiuchus — is called Serpens Caput (Serpent's Head). **Unukalhai**, the magnitude 2.6 star in Serpens Caput that translates to "Neck of the Snake," is also known as Cor Serpentis, Heart of the Serpent.

Southwest of Serpens Caput and trailing the tail of Hydra is one of the dimmest constellations of the zodiac. It is **Libra** the scales, formed in antiquity from the claws of Scorpius the scorpion.

Libra's pattern is a large diamond featuring the two bright stars Alpha and Beta. Alpha is a double star which is a tough challenge for the naked eye, even under excellent conditions; its components shine at 2.7 and 5.2 and are separated by slightly less than 4 minutes of arc. You'll have to split these two with binoculars.

While you have your binoculars out, check the unusual color of 2.6 magnitude Beta Librae. The asteroid Ceres passed just north of Beta in May and is still a 6th magnitude object only 4° to 5° west of the star.



skylore

It was perhaps not until after the time of Aratos during the 3rd century B.C. that the Greeks came to know a second Corona in the heavens — Corona Australis. Richard Proctor suggests that in very early times Corona Borealis may have been the right arm of Bootes, but R.H. Allen notes that the story of Ariadne's Crown was recorded at least as early as the 5th century B.C., by Pherecydes.

By the time of Plutarch, many variant threads were already woven into the story of Theseus and his trip to Crete where he met Ariadne, daughter of King Minos. The most popular version has remained the one in which Ariadne aided Theseus by giving him the ball of thread with which he was able to find his way out of the Labyrinth. That version reads that after killing the Minotaur, Theseus and the Athenian youths fled with Ariadne, but Theseus broke his vow to marry Ariadne and abandoned her sleeping on the island of Naxos.

But the story of Ariadne does not end with this heartbreaking betrayal. Dionysus observed the sad princess and fell in love with her, and pledged his loyalty to her in marriage with the gift of a marvelous crown. The crown is said to have been owned by either of two important sea goddesses, Thetis, the mother of Achilles, or Amphitrite, the wife of Poseidon. In both legends this crown was fashioned "of fiery gold and red Indian gems, set in the shape of roses" by the smith of the gods, Hephaestus.

One version of the tale goes on to say that after a long, happy life Ariadne died and was transported to heaven. In all accounts, upon her death Dionysus flung the crown up to the heavens where it shines forever in Ariadne's honor.

In Welsh mythology, our Corona Borealis was Caer Arianrhod — the castle of the goddess Arianrhod. The similarity of the names Ariadne and Arianrhod is striking, but apparently this is no more than coincidence. Arianrhod, whose name means "Silver Circle," does not emerge as a very comforting figure — she may in fact have been part of the mythic material that went into the making of Arthur's crafty and treacherous half-sister, Morgan le Fay. Caer Arianrhod was apparently a kind of purgatory for lost souls. It has sometimes been identified with the revolving castle ever protected by archers, Caer Sidi.

Stories about Corona Borealis are found all over the world, but some of the most interesting come from the American Indians. A tale in which the Great Bear is hunted and wounded in autumn to stain the foliage with his blood suggests Corona Borealis as the bear's winter lair.

An equally charming legend in which the stars of Corona Borealis play a central role is the Pawnee story of Algon and the twelve heavenly sisters. These sisters would come down from the sky in a magic basket to dance on the grass. They were observed by a hunter called Algon (White Hawk) who leaped up and seized the youngest and fairest of the maidens. The other sisters had to flee back to heaven without their favorite, but she soon fell in love with Algon and was content to be his wife — for a time.

It was a few years later, after the young star-maid and Algon had a son, that the girl's desire to see her home and sisters grew great. Algon returned from a hunting trip just in time to see his wife and son rising into the heavens in a magic basket. But the young maiden, though happy to be home, grieved to be without her husband, so her father allowed Algon to come as a white hawk and to roam freely with the young maid from heaven to Earth and in the airs between.

In this story, Algon is Arcturus, and the sisters are the stars of Corona Borealis — but their dancing circle is incomplete, because the youngest and fairest roams with Algon.

On the night of May 12, 1866, a real-life story nearly as fantastic as a myth began to unfold. On that evening a previously telescopic star about 1° south of Epsilon (ϵ) Coronae Borealis flared up to outshine Gemma and reached a magnitude of 2.0. It was named "The Blaze Star," officially T Coronae Borealis, and it would have been remarkable enough if it had merely been a very bright nova. But there were suspicions that this object was not an ordinary exploding star.

Those suspicions were confirmed, and the wonder of the object multiplied on February 9, 1946, when the Blaze Star burst forth again in splendor. It was 3rd magnitude, but probably on its way down, so it may have equalled its 1866 appearance.

This star, apparently the brightest member of the small class known as "recurrent novae," may have blazed forth to maximum other times and not been noticed — so quick is its rise and fall. (In 1866, it took just 8 days to fall from maximum to below naked-eye visibility.) Always check the pattern of the Northern Crown when it is in your part of the sky; you might be lucky enough to catch the next performance of the Blaze Star.

ASTRONOMY IN FOCUS

On Burnham on Burnham

Sir / The last thing I expected to hear from the author of one of the most moving pieces of science writing I've read — the introduction to *Burnham's Celestial Handbook* — was a rejection of the challenges and opportunities of space. In his self-interview, Robert Burnham, Jr. states that space colonists can never solve the population problems of Earth. He says, "It seems to me that mankind will stagnate and degenerate more rapidly in a space colony than it will here on Earth."

People and animals who leave one place for another do not think of themselves as either cowardly or noble. They are simply survivors — the smart ones who have in the past gone on to build the future. Einstein left Nazi Germany when he saw what it had become. Precambrian fish left the water to exploit the land — the fish who stayed behind remained fish.

To state that the people who remain behind would receive no benefits from space exploitation is simply not correct. But worse than that, it shows that the objector feels no link to the future. No matter who we are, we are a part of humanity. No matter what humanity will become, we will have been a part of it. To deny this is to forsake responsibility for our children.

Raymond Spizzirri
Chicago, IL

Sir / Congratulations to Robert Burnham, Jr. and his interviewer in your 1982 March Forum. They presented some marvelous intellectual nutriments for us to crunch on. In a mere five pages, Burnham produced a witty and irreducibly clear evaluation of economic glories and frustrations, of scientific advancements and dysfunctions, of the terrestrial and extraterrestrial, of skeptics and visionaries — and of the superb achievement of the 2,000 page *Handbook*.

I hope ASTRONOMY will not be afraid to continue spicing its Forum pages with such condiments as history, politics, ecology, economics, mythology, pseudo-science, religion, etc.

Thomas A. Kloepping
Dumont, NJ

Sir / If ASTRONOMY readers didn't know prior to reading Mr. Burnham's self-interview that his *Handbook* is 2,000 pages long, surely they are aware of it now. He mentions it seven times. It was tiring to hear Mr. Burnham toot his own horn so much. Please spare us self-serving self-interviews.

D.J. Nerren
Springfield, MO

Open Letter To Ronald Reagan

Dear Mr. President:

Over the last year I have listened to countless speeches and statements made by you calling for drastic measures to help our economy and balance the national budget, and pointing out that now is the time to act for the good of our future. I compliment you on the courage needed to take such steps.

But at the same time I have seen American space sciences almost totally forgotten and cut back to the point where their very future is in doubt and they face extinction — and I cannot help but notice the contradiction. You call for far-sighted policies, yet your Administration is the most short-sighted and indifferent in recent years when it comes to science.

I am sure you are as proud as the rest of the nation is of the team of scientists and engineers who design and conduct planetary missions of exploration; America is privileged to have them. These people represent the best of this country's scientific minds — sharpened by years of experience and success upon success — and they are the best in today's world.

With no forward-looking program of planetary exploration, the disbanding of such a team would be nothing short of tragic. Never in history has a great nation conducted such radical "brain surgery" upon itself.

Mr. President, ever since I was seven and was old enough to look at the stars with any amount of understanding, I have planned on making a career in some field of space science. I am now 21 and I share this dream with thousands of other young people. It is hard to believe that our vision of the future will be all but wiped out by a single stroke of your pen. Even this country's hopes for the future will suffer, for colleges and universities that produce such talents are struggling now as never before under your economic policies.

You speak of a "New Spirit of America" like this country's fathers had, and you say that we should look to the future. Yet you deny this country the scientific talents which helped make it what it is today. Everywhere I look I see scientific programs going down the drain as a sacrifice for your "budget." Does the U.S. really want to take second or even third place in the world of science? The Reagan Administration is already earning its place in history as the administration that killed American science.

Joseph M. Horodyski
Stamford, CT

Space & Military vs. Mankind

Sir / In the January In Focus, Donald F. Robertson suggested that we should accept or promote the military space program in order to keep our exploratory space program. I couldn't help wondering if Robertson's middle initial stands for Faust, who sold his soul to Mephistopheles in exchange for knowledge. Robertson is suggesting that in order to explore other worlds we should participate in the destruction of this world.

Building battle stations and laser systems in space will not bring peace on Earth. It will only add new layers of complexity and power to military systems already dangerously complex and precarious. It will only start the most expensive round in the arms race yet, a new round of counter measures and counter counter measures, which in the end will leave us only less secure. Somehow we still haven't learned this lesson.

And let us not forget that today the planetary program is being starved to feed the arms race. If we continue this arms race and expand it into space, it may take even more money away from science — and urgent human problems. But even if military space systems make it easier to explore other worlds, they will also make it easier for humans to ruin this world. I for one am not willing to see four billion years of evolution turned to dust in order to get a closer look at the dust of Mars.

Don Lago
Columbia, MO

Space Futures

Sir / During the past few months I have read nothing but bad news about the future of this country's space program. I know that budget cuts must be made, but why do they have to bite into such an important and highly productive program as NASA?

I am a university student studying to be an astronomer. If NASA is forced to experience a slow death by more and more cuts, my future will suffer the same fate. I wonder if our leaders on Capitol Hill and in the White House realize what they are doing to the futures of so many young astronomers?

I have personally written President Reagan and several Congressmen about the future of NASA. I encourage everyone who believes in advancement in science, and especially astronomy, to take action by writing their representatives in Washington. It might even help to drop a line to President Reagan.

ASTRONOMY magazine has had great coverage of the effort to stop the burial of our country's space program. I congratulate you, the editors and staff, for a job well done. Keep up the fight!

Jeff Mangum
Orland, CA

Praise for Galileo

Sir / The article on the Galileo Mission was fascinating. I'd sure like to be around in 1989 when the probe swoops down on Jupiter, and for the two years following, as the orbiter does its *dos-a-dos* with Ganymede, Io, Callisto, and the rest of the jovian family.

But it's quite a long way off for someone like me who is closing out his seventh decade, so I'm particularly happy to have your preview to enjoy — while I'll continue to make an effort to stick around for the real thing at the close of the next decade.

To move out a bit in our solar system, I take issue with the statement on page 63 of the February issue that Neptune "is now considered the most distant planet, since Pluto's highly eccentric orbit periodically brings it closer to the Sun than Neptune travels in its orbit."

Well, Pluto is now inside the orbit of Neptune, and will continue to be so until almost the end of this century, but during more than 90% of its quarter-millenary year it lies beyond the orbit of Neptune.

I would therefore think Pluto still deserves the title of the "most far-out" planet!

Arthur J. Morgan
New York, NY

Ooops!

The photograph of Coma Berenices on page 109 of the April issue was taken by L.H. Price, not Jack Marling. Our apologies.

behind the scenes | observing weather again

As we finish work on the June issue of ASTRONOMY, Spring has just begun. The last of the snow has nearly melted off, and even though puddles still freeze at night, it's not too cold for observing. I tend to use my 4 and 6-inch telescopes in winter since they're easy to carry out and set up, but with warm weather back, the time has come to take off dust covers and start using bigger instruments again.

Last night was particularly clear, so I put my 10-inch reflector — the Dobsonian whose construction we described in the June, July, and August 1980 issues of ASTRONOMY — out in the yard to cool down. Then I went in and sat down to edit a lengthy manuscript and forgot all about it.

At bedtime, I suddenly remembered the telescope — still outside. I felt tired and grumpy, cross-eyed from too much reading, but didn't want to leave it out. For all I knew, it was raining. So I put on my coat and went outside, half expecting clouds — but the sky was clear. Mars, Saturn, and Jupiter shone brightly in the southeast.

"Okay," I thought, "I'm tired, but I'll take a quick look at you." I went back in, got my eyepieces, and came back out.

I looked at Mars first — it snapped in sharp, clear, and crisp — the seeing was rare, excellent. Since the mirror was a bit out of alignment, I spent a few minutes lining it up to give perfect images, then looked at Saturn. I won't even try to describe it — your imagination can fill in the details of Cassini's Division crisply etched on the rings, Titan and three tiny attending moons, and the delicate grey-blue and yellow tints of the planet and rings better than I can.

"This is the best I've seen you since Voyager," I said to Saturn. I looked at Mars again, taking in the polar cap and the dull green markings on its orangey globe. Then I studied Jupiter, lower in the sky, still in somewhat murky air.

When my neighbor came out to move his car, he came over to see the planets. Then a man walking down the street joined us, and remembered the dark skies over the Colorado town where he'd grown up.

When I finally carried the telescope inside, I felt refreshed.

Sincerely,

Richard Berry

Richard Berry
Editor

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eclipse chaser's notebook: 1983 to 1991

gazer's
gazette

by
Fred Espenak

Next to volcanic eruptions and earthquakes, solar eclipses are probably the most awe-inspiring events in the natural world. When we stand in the path of totality, watching that last thin sliver of Sun dwindle to nothing and vanish, we *know* why pre-scientific civilizations dreaded solar eclipses. We may think we're above all that superstition — this is the 20th century, after all! — but some primitive part of us still worries that the warm, life-giving Sun has just been turned off for good.

A few splendid minutes pass — lit by the soft pink-white light of the corona and a ruddy prominence or two — and then a swift brightening in the west announces the end of totality. A blinding flood of sunlight drives away the corona and restores the landscape to something like its normal appearance. Though the Moon will take another hour to uncover the solar disk, for all practical purposes the show is over.

Every 29½ days, the Moon cycles through its phases as it orbits the Earth. It may seem as if we ought to see a solar eclipse every time the Moon passes through New, but we don't. Why not? Because the plane of the Moon's orbit is tilted with respect to the Earth's path around the Sun. They cross each other at only two places, called nodes. And only when the Moon passes through one of the nodes near New Moon do we see a solar eclipse.

Because occurrences of solar eclipses are both spectacular and predictable, they tend to generate a great deal of interest among amateur and professional observers. And they're not just flashy sky shows: a total solar eclipse offers virtually the only Earth-bound opportunity to observe the Sun's corona — a faint, tenuous, and very hot atmosphere which surrounds the Sun.

Over the course of the next ten years, the Moon's shadow will sweep across the Earth's surface 22 times. Of these eclipses, eight will be partial, six annular, six total and two annular/total eclipses. The map on pages 40-41 displays the paths of all annular, total and annular/total eclipses until 1991. Partial eclipses have been omitted. Let's take a look at the particulars.

11 June 1983

The first eclipse in our survey is total with a very long duration. The path of the Moon's shadow begins at sunrise in the Indian Ocean and quickly swings northeast. First landfall for the moving umbra occurs along the southern coastline of Java. Traveling at close to twice the speed of sound, the shadow will sweep across the island in six minutes.

Observers stationed in the path are likely to encounter clear skies as the noontime Sun's disk is completely obscured for over five minutes. After Java, the path of totality crosses the southern Celebes Islands and reaches New Guinea in the late afternoon. Continuing out across the Coral Sea, the umbra leaves the Earth among the New Hebrides Islands.

This eclipse occurs about midway in the 11-year sunspot cycle: four years after maximum. Accordingly, the corona may display structures characteristic of both high and low sunspot activity. The 1973 eclipse exhibited this type of corona. Look for both equatorial streamers and delicate polar plumes. The prospects for observing prominences along the Sun's limb are not very good. We probably won't see a repeat of the fine displays seen during the 1979 and 1980 eclipses.

The Sun will lie among the bright winter constellations, making this a good opportunity to gauge the sky brightness during totality. Both Venus and Mercury should be easy to see and Mars will shine a scant 2° west of the Sun. Outside the path of totality, a partial eclipse will be widely visible from southeast Asia, the Philippines, Indonesia, and all of Australia.

4 December 1983

The path of this annular eclipse begins in the north Atlantic Ocean and stretches across central Africa, where the Moon will be completely silhouetted against the Sun for four minutes. After crossing northern Kenya and southern Ethiopia, the path will stop in Somalia.

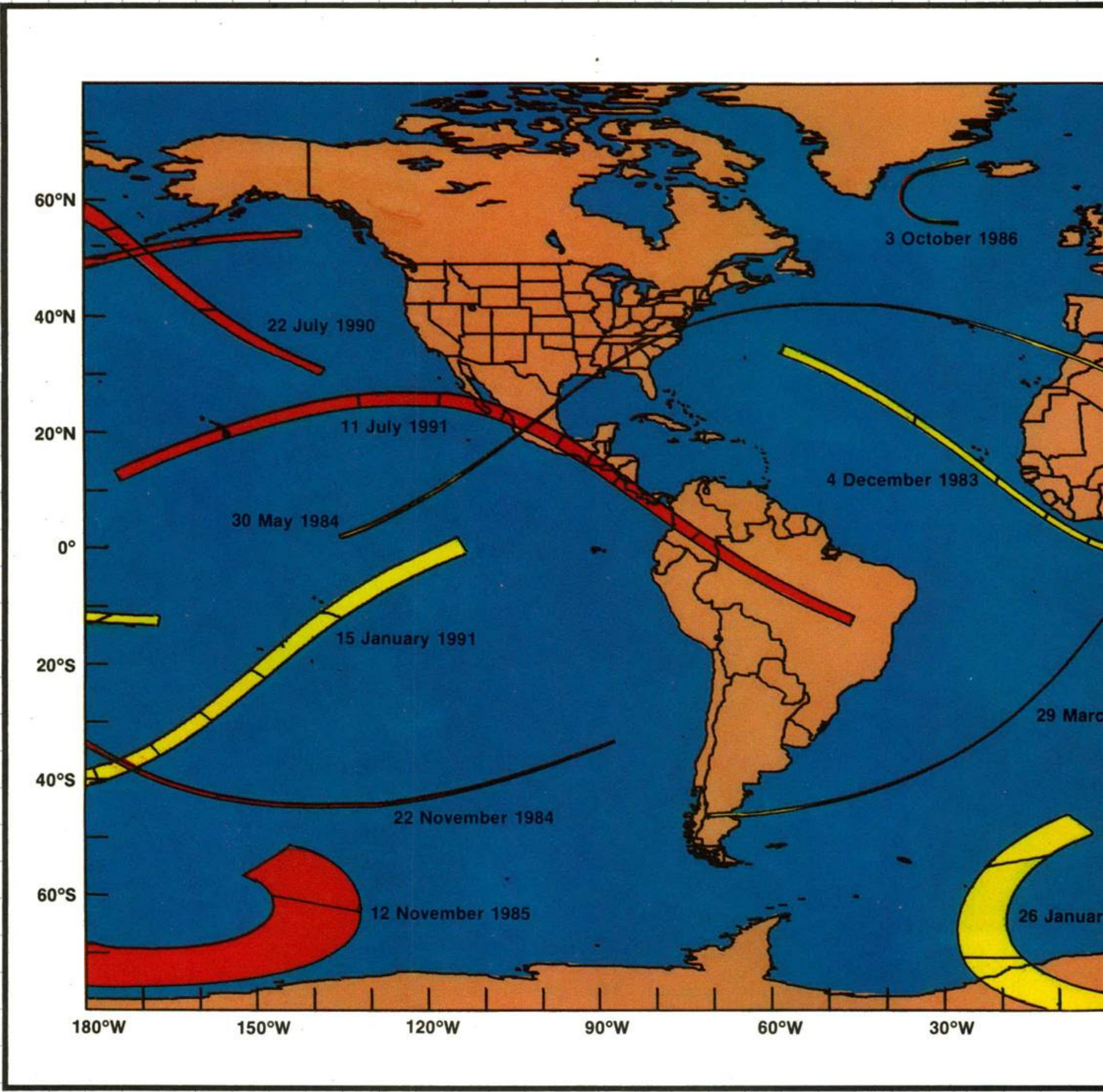
30 May 1984

This is an annular eclipse for those in Mexico and the southeastern United States. The rest of the continent — excluding Alaska — will witness a partial eclipse. After the path of annularity leaves the U.S., it will cross the north Atlantic and end in northern Africa. Observers across most of Europe will also see a partial eclipse.

This eclipse is unusual and short since the tip of the Moon's umbra skims past the Earth's surface a scant 725 kilometers up. For instance, the annular phase will last 15 seconds in Atlanta, Georgia, where the path will form a narrow corridor only 10 km wide.

Because the eclipse is so close to total, many observers will hope to see the solar corona. Unfortunately, 0.4% of the Sun's disk will remain unobscured at mid-eclipse — and the light from this annulus will be 1000 times brighter than the corona — so the sky will be flooded with scattered light. Despite this, the eclipse should produce a sky dark enough to reveal Venus only 4° west of the Sun.

Among the cities which lie in or near the path of annularity are New Orleans, Louisiana; Montgomery, Alabama; Greenville, South Carolina; Charlotte, North Carolina; and



Richmond, Virginia. Observers might want to visit one of these cities and make a final site selections according to weather predictions the day before the eclipse.

22 November 1984

The umbral shadow will first touch the Earth off the coast of the Indonesian island of Halmahera and then quickly sweep over New Guinea for the second time in less than two years. The path continues out across the Coral Sea where it passes 100 km south of New Caledonia and 435 km north of New Zealand. Then it crosses the south Pacific where the umbra leaves the Earth, 1600 km west of Chile. Maximum eclipse occurs northeast of New Zealand where totality will last a fraction under two minutes.

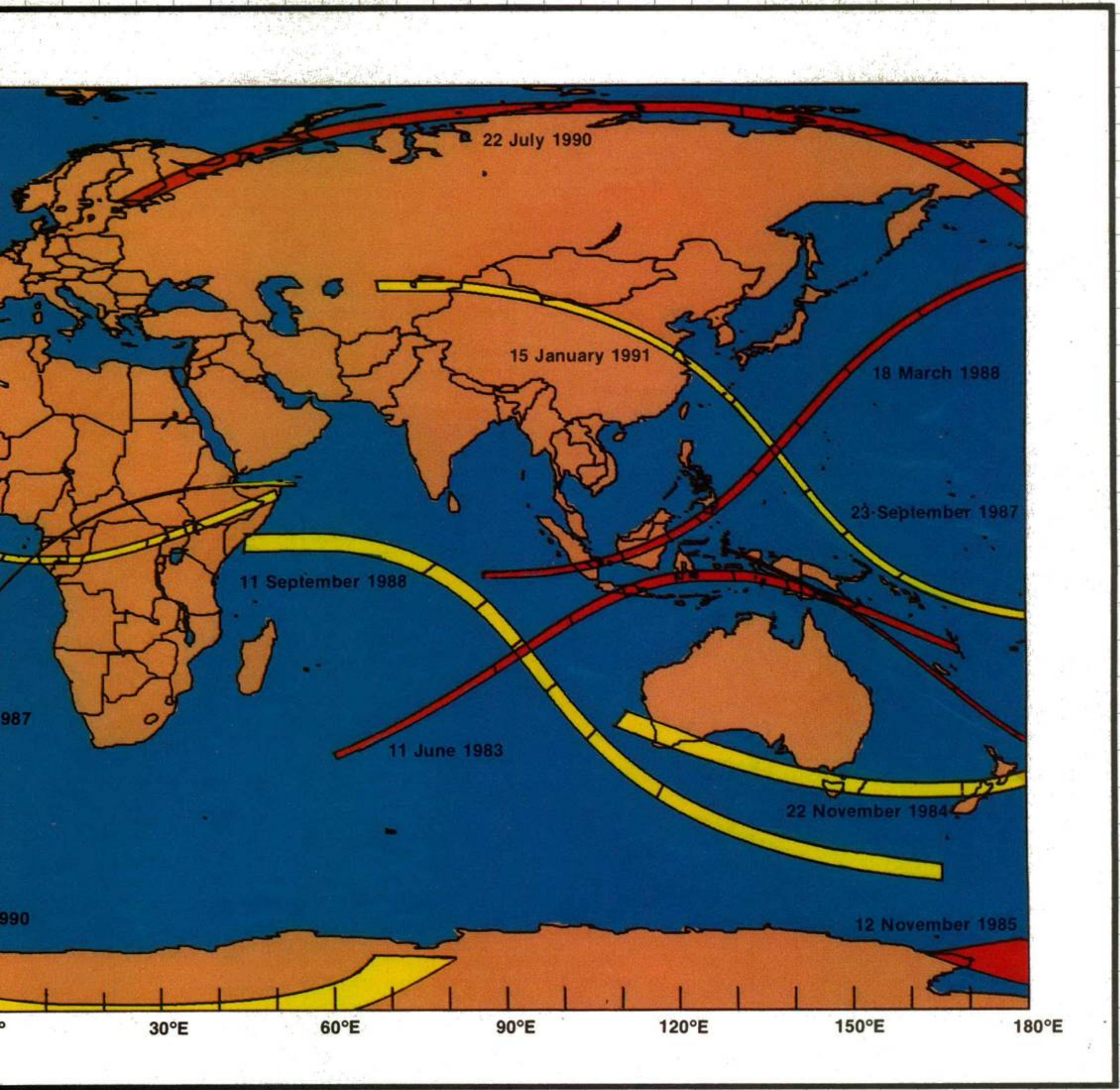
12 November 1985

This total eclipse is intriguing for a number of reasons. The path of totality begins in the south Pacific about halfway between New Zealand and southern Chile. Then it quickly swings southeast, crossing the Antarctic Circle where maximum eclipse will last 1 minute 58 seconds.

Just off the coast of Antarctica, the path changes direction and heads west. After sweeping across the iceberg-studded Ross Sea, the path skirts the flanks of Mt. Sabine and ends. This C-shaped arc will bring the umbra in contact with the Earth for 38 minutes.

As seen from the Moon, the umbra will describe a short "slice" across the Earth, very close to the edge of its disk. The oblique geometry of the umbra's path results in an eclipse track 700 km wide. In addition, the Sun's altitude will never be higher than 11° along a path which both begins and ends at sunrise!

At eclipse time Antarctica will be experiencing late spring. The unique characteristics of this eclipse, coupled with the chance to visit the bottom of



the world, should inspire at least one eclipse cruise to Antarctica.

3 OCTOBER 1986

Eleven months after the Antarctic eclipse, the umbra briefly sweeps over the opposite end of the world during this annular/total/annular eclipse. Beginning at sunset off the western coast of Iceland, the path of annularity is 60 km wide. It will travel southwest and quickly narrow to a point where the umbral shadow cone of the Moon first touches the Earth.

For the next 160 km, the path of totality rushes due south as it broadens to a maximum of 2.4 km. Continuing another 160 km south, the umbra leaves the Earth and the eclipse once again becomes annular. The path curves east and ends at sunset about 1100 km south of Iceland.

The entire sequence of events transpires in 21 minutes, but the umbra actually touches our planet for only six minutes. Theoretically, the maximum duration of totality is a scant third of a second. But this assumes a perfectly spherical Moon; well-placed lunar mountain ranges or a non-circular figure to the Moon's shape could mean that the corona might actually be visible for up to 20 seconds. If a mid-ocean rendezvous proves too difficult, observers can still enjoy a partial eclipse from all of North America except for the west coast.

29 MARCH 1987

The decade's second annular/total eclipse occurs just six months after the first; its path begins in southern Argentina. As it crosses the south Atlantic, the annular belt narrows and becomes total about 3200 km west of south Africa. Continuing on a northeastern course, the path of totality reaches its maximum width of 4.8 km in the middle of the south Atlantic. At this point, the total eclipse lasts seven seconds with the Sun 72° above the horizon.

Unfortunately, the path rapidly narrows again, becoming annular before it reaches the shore of Gabon in west Africa. The annular track stretches across the continent where it ends in the Indian Ocean east of Somalia.

23 September 1987

This annular eclipse's path begins in the steppes of Siberia and crosses into northern China. Over 95% of the Sun's disk is occulted during the 3½ minute annular phase. After passing over Shanghai, the path leaves the mainland of Asia and completes its course in the south Pacific. Most of Asia can expect to see a partial eclipse.

18 march 1988

The geometry of the Earth, Moon and Sun closely repeats itself every 18 years 11 days 8 hours. This is the famed saros cycle which was used by ancient civilizations to predict eclipses. On March 7, 1970, many people on the east coast of the U.S. witnessed a total eclipse as the umbra swept across Mexico and up the eastern seaboard.

One saros later — and a third of the way around the globe — a very similar eclipse will take place. The shadow first touches down in the Indian Ocean and rushes eastward. Sumatra, Borneo, and the southern Philippines lie in the path of totality as it curves toward the north. Maximum eclipse occurs 1600 km south of Japan and lasts 3 minutes 46 seconds. The umbra passes just south of the Aleutian Islands and leaves the Earth in the Gulf of Alaska.

11 September 1988

Beginning along the southern cost of Somalia, the path of this annular eclipse stretches out across the Indian Ocean with no other landfall. Maximum annularity lasts almost seven minutes before the path swings south of Australia and ends near New Zealand.

26 January 1990

The path of annularity for this eclipse starts in Antarctica and passes within 700 km of the south pole. The Sun will never climb higher than 20° for any watching penguins during the two minutes of annularity. After sweeping into the south Atlantic, the path ends midway between the Cape of Good Hope and Tierra del Fuego.

22 July 1990

This total eclipse belongs to the same saros family that produced the Canadian eclipse of July 10, 1972, and begins at sunrise in southern Finland. Helsinki lies near the center line where the Sun will stand a mere 1° above the horizon during the 1½ minutes of totality.

Quickly crossing into the U.S.S.R., the umbral shadow skirts the northern shoreline of Siberia. Maximum eclipse occurs along the Arctic Circle in eastern Siberia and lasts 2 minutes 32 seconds. The path swings south into the Bering Sea where several of the Aleutian Islands lie. Continuing south, the umbra leaves the Earth 2100 km southwest of Los Angeles.

15 January 1991

The sixth annular eclipse in our survey will be widely visible from "down under." The path begins just off the western coast of Australia and travels southeast. Perth lies near the centerline, where the Sun will have an altitude of 10° during the six-minute annular phase. Leaving the continent, the path crosses Tasmania and New Zealand, and heads into the southern Pacific Ocean where it ends at sunset.

Total, Partial, and Annular

On occasion, the Moon's outer, or penumbral, shadow will engulf a section of the Earth, and we see a partial eclipse. If the position is right, the Moon's inner shadow, or umbra, will sweep across the Earth as well — and any observer in its path will witness a total solar eclipse.

But the Moon's orbit is elliptical, and the umbra can't always stretch far enough to reach the Earth. If all the conditions are right for a total solar eclipse, but the umbra falls short, observers in the shadow's path will see a ring, or annulus, of sunlight surrounding the black disk of the Moon. These are called annular eclipses.

A fourth and rarer eclipse is both annular *and* total. These happen when the Moon is not quite close enough to Earth for the entire eclipse path to be total. Usually, the extreme ends will be annular, but the middle — where the Earth bulges out far enough to be grazed by the umbra — has an extent that is total.

11 July 1991

The final eclipse of this survey will also be the best. Total eclipses can last anywhere from a fraction of a second — as in the 1986 event — to a theoretical maximum of 7 minutes 31 seconds. But very long eclipses are extremely rare. In fact, only three so far this century have exceeded the seven minute mark — June 8, 1937; June 20, 1955; June 30, 1973 — and they all belong to the same saros family.

The great total eclipse of 1991 is also a member of this family and should be spectacular. In addition to its long duration, this event will be North America's last total eclipse until 2008. (See "Solar Eclipses in North America: the Next 50 Years," ASTRONOMY, November 1980.)

The umbra first touches the Earth's surface in the Pacific Ocean near the International Date Line. Traveling eastward, the shadow reaches Hawaii where the Big Island and southern Maui will be plunged into darkness for four minutes soon after sunrise. The observatories atop Mauna Kea — which contain a 4-meter scope and numerous others — are certainly well-placed! In addition, the treeless, almost lunar landscape surrounding the site should provide a perfect backdrop for this celestial drama. But the best is yet to come:

The umbra will sweep over the eastern Pacific with an average velocity of more than 3200 km per hour. Since the Moon is near perigee, its shadow will be broad. The path of totality is 260 km wide as it races over Baja California, and enters Mexico — where maximum eclipse occurs. On the center line, the total phase will last 6 minutes 53 seconds with the Sun only 2° away from the zenith.

In Mexico City, the midday sky will grow dark and Mercury, Jupiter, Mars, and Venus will be visible east of the Sun, strung out like a row of celestial pearls.

Swinging southeast, the shadow will follow the Pacific coast of Central America. Parts of Guatemala, El Salvador, Nicaragua, Cost Rica, and Panama all stand in the path of totality. The umbra sweeps across Colombia during the mid-afternoon and leaves our planet over central Brazil.

During the next ten years, a fanatical eclipse chaser who managed to be in all the right places at the right times — and had the luck of perfect weather — could observe the Sun's elusive corona for a total of 22 minutes and 27 seconds. Although most of this decade's eclipse paths are not as conveniently placed as those of the past decade, many are relatively easy to reach.

If the example of the past few decades holds true, eclipse chasing will remain a popular though expensive way to combine exotic travel with a wonderful celestial sight.

Fred Espenak is an infrared astronomer at NASA's Goddard Space Flight Center in Greenbelt, Maryland, where his current research involves modeling planetary atmospheres. He is a veteran of six eclipse expeditions.

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10″ Model DS-10
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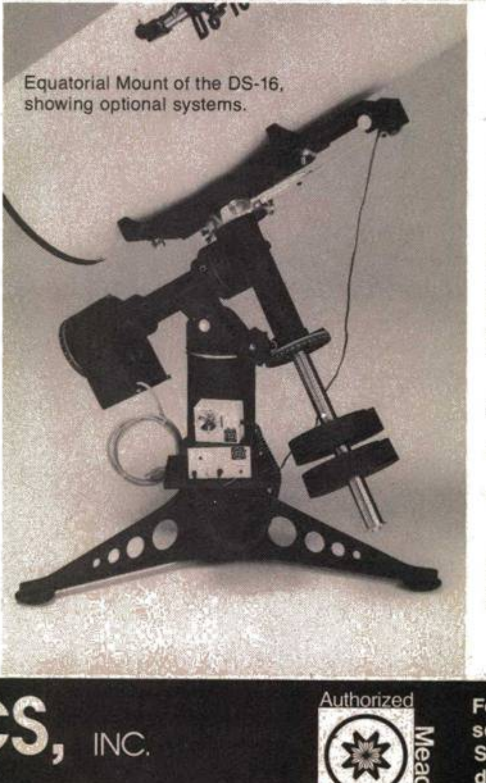
Shown equipped with optional motor drives, setting circles, viewfinders.



Equatorial Mount of the DS-16, showing optional systems.

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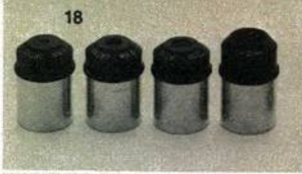
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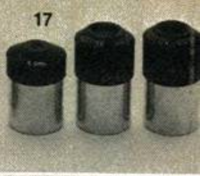
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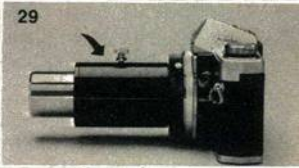
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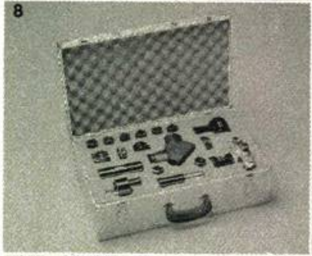
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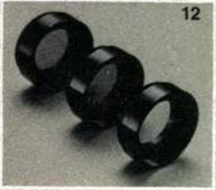
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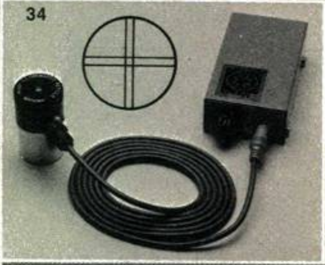
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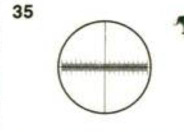
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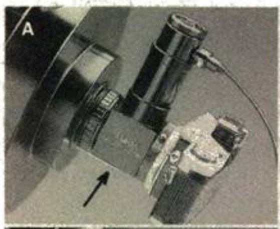

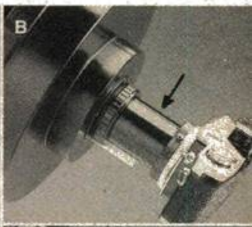

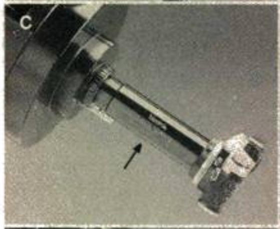

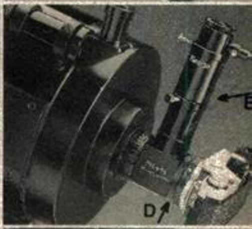

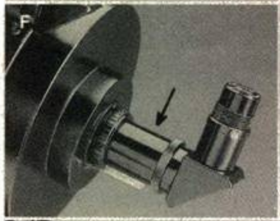

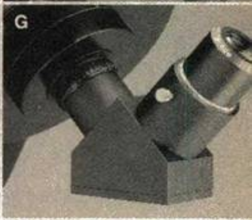

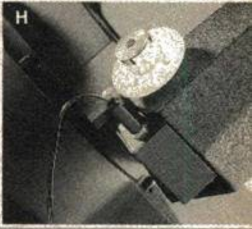

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Perfection's XR-1 is one of the most remarkable black-and-white developers on the market today. It is designed to bring out the maxiumum speed in any type of film without producing unacceptably high contrast — and it works very well with some films.

XR-1 replaces the discontinued Super-Speed and High Speed/Fine Grain developers made by Perfection and gives film speeds of 1600 with Tri-X, just short of 800 with Plus-X, and 300 with Panatomic-X. The speed of 300 (ASA equivalent) with Panatomic-X — which is normally ASA 32 — is nothing short of amazing.

On the other hand, my roll of Plus-X had more fog and less contrast than I would have liked. With other films, XR-1 is even less spectacular. Ilford's FP4 and HP5 didn't respond well to XR-1. The developer also performs poorly with Technical Pan 2415; its speed of ASA 80 is not much higher than what you'd get with conventional developers.

This increase in speed is possible because the official ASA numbers apply to films developed in a standard solution with a metol-hydroquinone formula similar to D-76. XR-1 is a phenidone-based developer, and unlike most others (such as Microphen) which increase the true speed by about half a stop, it increases it much more.

In return for the increased speed, your film prints a bit grainier than it would with normal developers — but this is counterbalanced by the finer-grained films that you can switch to. And depending on the dilution you use, it can cost over a dollar to process a single roll in XR-1 — so it's one of the most expensive developers on the market.

In addition, XR-1 is by no means easy to use. The film has to be given a prebath in diluted Photo-Flo. And you have to get the prebath, developer, stop bath, and fixer all to the same temperature (usually 90° F) at the beginning of the session and let them drift together toward room temperature. This isn't easy if you're not set up to control solution temperatures.

From the astronomical point of view, the most useful thing about XR-1 was mentioned earlier: Panatomic-X has a speed of ASA 300 when processed in XR-1, which means that you can use a practically grainless film in situations that otherwise would force you to use Tri-X. This works ideally for lunar and planetary photography.

For deep-sky objects, XR-1 is far from ideal for two reasons. First, it is essentially a low-contrast developer. (This allows it to develop the emulsion very thoroughly without producing excessively high contrast.) Second, like all phenidone developers, it produces more than the usual amount of fog. For jobs that call for high contrast and low fog, stick with HC-110 or D-19. *Michael Covington.*

All About Telescopes

Sam Brown
192 pages, paperback, $10.95;
hardcover, $21.95
Edmund Scientific (1981)

When I received my copy of the latest edition of *All About Telescopes*, it was like greeting an old friend; about 15 years ago, its first edition — together with Patrick Moore's *Amateur Astronomy* — taught me how to observe the sky. Now both books are again on my shelf, and I feel as though some cosmic cycle is complete.

This is a book about telescopes that also says a good bit about astronomy — rather than a book about astronomy that happens to discuss telescopes. It concentrates almost wholly on the equipment of observing: telescopes, eyepieces, binoculars, and cameras. It also combines several of the author's earlier, shorter books, and it excels in Sam Brown's specialty — diagrams. At least three-fourths of the information in the book is presented in graphic form; this makes for excellent browsing. You can learn a lot by opening it at random and just studying the pictures.

The first two chapters of *All About Telescopes* explain basic observing techniques and include star charts, the best diagrams I've ever seen explaining celestial coordinates and equatorial mounts, and a very good discussion of how to find celestial objects.

A section on astronomical photography provides many details on optical configurations. Refreshingly, it also gives conservative estimates of what a beginner can expect to do: "the sample pictures are not blue ribbon winners, but are exactly the kind of pictures you will get the very first time out if you follow a few simple rules."

The section on grinding mirrors is thorough and could serve as a handbook for anyone who chooses to make his own Newtonian optics from scratch. Following that are detailed plans for dozens of telescopes and mounts — ranging from a modified monocular to a 6-inch Newtonian. Sections on telescope adjustments and optics (including the graphical method of ray tracing) round out the book.

Although I don't hesitate to give *All About Telescopes* a high recommendation, it does have some weaknesses, including very little revision since the first edition appeared in 1967. In many ways it is becoming out of date.

The book's emphasis lies very much on small and medium-size homebuilt Newtonian telescopes with equatorial mountings. It covers refractors, but it doesn't mention compound optical systems such as Maksutovs and Schmidt-Cassegrains. At the very least, the book could have provided one or two illustrations of these popular telescopes.

Most films listed on the film-data table have long since been discontinued, and the book's filter table uses the old letter designations — already obsolete in 1967 — rather than the now-standard Wratten numbers. In addition, *Telescopes* ignores recent techniques such as chilled emulsions and gas hypering.

Despite these complaints, *All About Telescopes* is one of the most informative books an amateur astronomer can have; it ought to be in everyone's bookcase. Let's hope that the next edition will take care of the faults and make the book even better. *Michael Covington.*

Practical Astronomy with
Your Calculator (second edition)
Peter Duffett-Smith
188 pages, paperback, $9.95;
hardcover, $29.95
Cambridge University Press (1981)

First published in 1979, *Practical Astronomy with Your Calculator* has found enough popular acceptance for its publisher to bring out this revised and enlarged edition which includes 23 new topics and 59 additional pages. Anyone who has a scientific calculator or home computer and a working knowledge of algebra can use this book to calculate the date of almost any astronomical event — from the position of the Moon next October to the date of Easter in 2012.

Practical Astronomy approaches its subject as a cookbook does a stew: it teaches the how, not the why. But its explanations are easily understood — and each calculation is worked through with example to help you stay on the right track.

The author recommends the reader have a calculator with at least trig functions (sine, cosine, tangent, and their inverses) and also advises using a model with several memory locations. If you think you'll use any of the procedures often, you'd do well to consider a programmable calculator.

Some of the book's calculations are complex, and beginners could have trouble the first time through them. And while the book generally lacks any long or extended formulae, you may have to refer back to previous sections to solve some problems. Calculating a lunar eclipse, for example, calls for delving into at least two other sections of the book.

Although the results you'll get using these calculations are not as accurate as those published in the *Astronomical Almanac*, they will be adequate. And since your calculator or computer will be doing all the tiresome work, you may find it an enjoyable challenge to chart out your own list of astronomical events. *Michael L. Ray.*

The Physical Universe
Frank S. Shu
584 pages, hardcover, $28
University Science Books (1982)
[publisher's address: 20 Edgehill Rd., Mill Valley, CA 94941]

Taking a slightly different approach from that used in many textbooks, Shu emphasizes the "deep connections between the microscopic world of elementary particles, atoms, and molecules, and the macroscopic world of humans, stars, galaxies, and the universe." The use of mathematics is somewhat more prevalent than in most texts.

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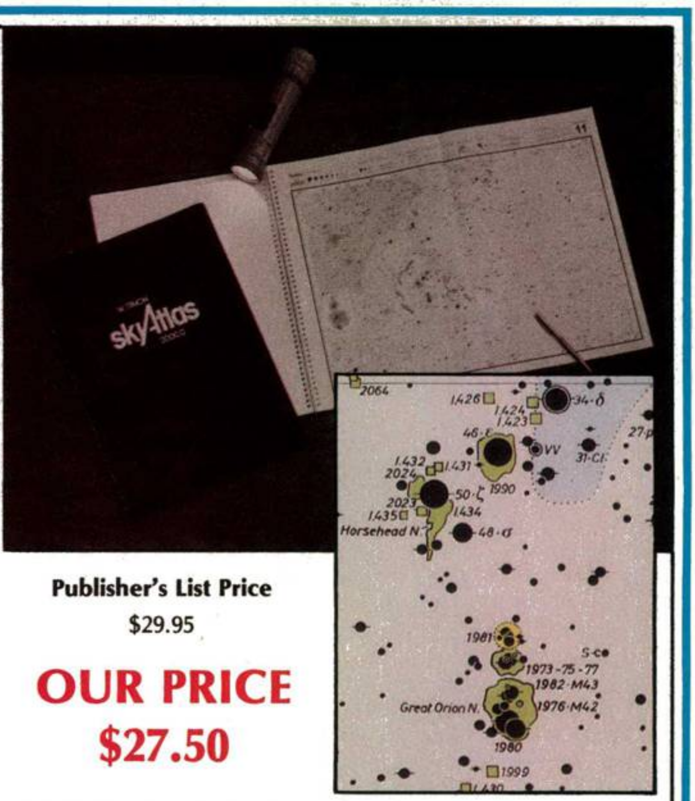

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equipment
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rethinking your 60mm refractor

by Ernest Underhay

With the rise of the U.S. space program in the '60s and early '70s, we also saw a dramatic rise in the popularity of astronomy. Part of this was due to the availability of vast numbers of inexpensive refractors with 60 millimeter aperture, or, before we became partially metricized, 2.4 inches. Indeed, many professional astronomers and people who today regard astronomy as a serious pastime, first viewed the heavens through one of these "two-point-fours."

Quality was variable, ranging from nearly useless junk to sturdy, well-mounted instruments that delivered exquisite definition. All but the very worst and very best shared similar strengths and weaknesses.

On the positive side, they usually gave crisp sharp images reasonably free of color. But not always — I remember a friend who purchased a 2.4 from a discount house. He proudly described the beautiful oranges and blues his scope showed on Jupiter. It was his lens, not the universe, which gave him psychedelic visions of the giant planet.

These scopes were easy to set up — and surprisingly forgiving of the rough treatment dished out to them by neophyte stargazers. Their portability allowed short viewing sessions in cold weather, and their ease of operation saved beginners from the hi-tech hassles of equatorial alignment, collimation, and drive adjustments. You looked through the telescope, and you saw things.

On the other hand, the mounts were often flimsy, and the finders were frequently terrible. The performance of a good objective lens was frequently marred by small eyepieces giving narrow fields of view and too-high magnification.

Nearly all of these small refractors were imported from Japan. But during the '70s, the average price of the imports soared as the yen rose in value relative to the dollar. Meanwhile, American manufacturers began turning out a growing variety of competitive instruments.

So the old 2.4-inch is largely abandoned today. The beginner is apt to start with a much more sophisticated instrument than his counterpart fifteen years ago ever dreamed of. But many of those old 2.4s are still around, keeping a low profile these days. After an initial period of intense use, they might have been replaced with a 6-inch reflector or stored away in the attic by an owner unwilling to take the time to explore the instrument's full potential. Now they're re-emerging in rummage sales, yard sales, and local telescope and camera shops. And the price is usually right.

> *...they're re-emerging*
> *in rummage sales,*
> *and the price is right.*

In return for a couple of hours of gluing, refurbishing the mount, perhaps making the tripod heavier and stronger, maybe even collimating the lens, you can correct past abuses. The most valuable alteration you can make is opening up the drawtube to accept 1.25" eyepieces. For the price of a $3 plumbing component, you'll be on your way to discovering, or rediscovering, the joys of owning a small, portable refractor.

The original owner of the scope I resurrected must have knocked it down a couple flights of stairs. It had a plenty of dents, and came without eyepieces. I removed the old focuser, bought six inches of 1¼" chrome-plated sink drain at the local home and fix-it shop, and converted to American Standard — eyepiece sizes, that is. All it took was a couple of tight-fitting wooden plugs to hold the chrome tube, a bit of glue, and a 1¼" star diagonal.

From my suburban backyard under fairly hazy skies, the stars glitter against the dark, almost black, sky. The images are crisp and sharp and show pinpoint stars even at the edges of wide-field Konig and Erfle eyepieces. Low-power views are breathtaking, and cover nearly 2° — enough to include the whole Pleiades or Beehive Cluster.

Contrary to what the sellers of these telescopes might have had you believe, 60mm of aperture does not "pierce indifferent seeing like a rapier." Rapiers have notoriously poor light grasp anyway. Nor can it "duplicate the performance of larger scopes" — only larger scopes can do that. An eight-inch will always gather more light and resolve better than a 2.4.

On the other hand, a 2.4" f/15 is less subject to the whims of poor seeing and can give a more pleasing view from a light polluted location than a larger scope.

The Moon is the obvious first target — easy to find and showing a wealth of detail to every observer, regardless of equipment. Turn your revitalized refractor toward it. Its smaller light grasp — coupled with long focal length and excellent contrast — combine to provide full disk views of our satellite that are often more pleasing than those of larger instruments.

Free of the glare of surplus light, your eye can pick out details that only emerge at higher powers with larger scopes. I'd need a book to describe all the wonders of the lunar landscape. You can see radial banding on the walls of both Copernicus and Aristarchus. And Plato's dark floor shows at least one bright craterlet at 90x. The full disk of the Full Moon through the 2.4 is better than what you'd see through about any other

Photo by Richard Berry

instrument. The maria look dark and crisp against the bright uplands. Each rayed craterlet stands out starkly against its lunar background.

The planets also benefit from the relatively long focal ratio and excellent resolution of your "new" scope. Venus, at 90x, easily shows its full complement of phases, and is often best seen an hour or two before sunset when the glare of the planet is muted by daylight.

During its unfavorable 1980 opposition, Mars never exceeded 13.8" as seen from Earth. Nevertheless, a magnification of 90 revealed a tiny star-like north polar cap gleaming atop the small ruddy disk of the planet. Even though the planet was small, it showed quite a bit of detail. I followed the shrinking of the polar cap as it melted during the martian spring. In moments of excellent seeing, I found the polar cap bordered by a dark collar, perhaps the enormous dune fields photographed by Viking. I could even spot the larger classical markings such as Syrtis Major and Sabaeus Sinus and follow them as they rotated onto the disk, crossed its center, and faded away toward the sunset limb.

Even at the lowest power, 22x, Jupiter's moons show up as four little stars escorting the tiny bright disk of the giant planet across the field of view. A 90x magnification makes Jupiter appear twice as big as the Moon does to the unaided eye and reveals the major dark belts and bright zones. At 132x the planet reveals subtle details in good seeing. I viewed irregular and scalloped edges of major belts, a thin broken equatorial belt and a narrow dark region in the north equatorial belt resembling in size and shape the "barge" photographed nine months earlier by Voyager 2. I can also see the moons of Jupiter casting tiny ink-spot shadows on the planet, or slowly fading from view during eclipse. Transits are very challenging, or impossible, since there is very little contrast between Jupiter's disk and those of its satellites.

Saturn offers a thrill to those not jaded by Voyager vistas of rings and moons, or seduced by the lure of big telescopes. At 90x, I can see all the basic features of the planet and rings, in addition to Titan and often Rhea. In 1980, when the rings were invisible and the glare from the planet less obtrusive, I could also see Tethys and Dione.

At high powers, Saturn reveals a bright equatorial zone bordered by a dusky belt and the black, pencil-thin shadow of the rings on the disk. I glimpsed Cassini's division in May 1979, mere months before the rings went edgewise.

On leaving the solar system, we enter a universe dominated by objects which are faint and often difficult to observe. For these, a 60mm scope may seem inadequate, but its pinpoint-sharp images provide views of many deep-sky objects more impressive than you might expect. In any case, since super-good portability makes quick trips to mountain skies easy, you are more likely to use it. After all, a 2.4 on a clear, dark mountaintop is worth a large Dobsonian in city backyards, plus several heavy equatorials thrown in for good measure.

From the mountains on a pitch-black night, I sighted a 12.6 magnitude star in the AAVSO's R Aquarii sequence, and I may have seen a 13.1 star. On that same night, the brightest segment of the Veil was swept up easily, spanning the entire 28x field as a dim and mottled arc. Elusive and frustrating M-33 showed a brightish central region surrounded by a distinct hazy glow. At its edge I saw the giant starcloud NGC-604 as a small fuzzy spot.

With a 40mm wide-angle eyepiece, I've had breathtaking views of the clustered pairs and triplets of stars in the Beehive and the faint haze of nebula extending south from Merope in the Pleiades. Both M-35 and M-38 show well at this low power, with the more remote clusters NGC-2158 and NGC-1907 showing as dim neighboring patches of fuzz. Adding to the view, each of these clusters has a red star nearby, hanging in the foreground of the field, providing a three-dimensional perspective into the depths of our galaxy.

In addition to the familiar Messier objects, some of the obscure NGC and IC objects are attractive targets — especially large, loose scattered clusters such as IC-4665 in Ophiuchus or NGC-1647 with a couple of the Hyades in the foreground.

Globular clusters, more remote and compact, do not fare as well. Most appear merely as hazy oval patches of light — but there are exceptions. At 90x, M-22 is a large amorphous hazy blur with many tiny stars scattered over it. Another loose globular, M-4, begins to resolve hints of its north-south trending bar. The great globular M-13 is a bright round grainy haze framed by about a dozen faint stars. Even the nearby galaxy, NGC-6207 — often considered a test for much larger scopes — appears under perfect skies as a tiny, non-stellar, patch of light.

Half of the stars in our part of the Milky Way belong to double or multiple systems. If the lens in your old refractor is a good one, it can provide excellent views of many pairs even on nights of mediocre seeing. A warning though — the light grasp of a 2.4 sometimes fails to reveal faint companions lurking in the glare of their primaries.

Epsilon Lyrae, Castor, Epsilon Bootis and 70 Oph all show up under high power with a 60mm objective. Crisp stellar images against the dark sky background add sparkle to old favorites such as Albireo and low-riding, often hazed-out, systems such as the Gamma Velorum triple.

Planetary nebulae present a challenge, although their often high surface brightness aids in identification. M-57 presents a tiny disk in the star-studded field at 22x. With 90x and averted vision, the smoke ring reveals, though dimly, a definite central hole. Some of the smaller planetaries show up rather well — the tiny disk contrasting with the pinpoint stellar images seen at 35x.

The larger diffuse nebulae are special treats when seen from rural locations. A wide-field eyepiece and a dark night may combine to provide plenty of black sky as a backdrop for these large elusive objects. M-8, the Lagoon Nebula, shows especially well; its three main patches of nebula separated from each other by dark lanes are all followed by a pretty little cluster of stars. The nearby Trifid is a real challenge, but the main portion shows up as a faint, unmistakable haze crossed by dark lanes with a tiny pair of stars at its center.

The Orion Nebula is glorious at 22x, set in the midst of the whole Sword of Orion. Even 35x constricts this field, isolating individual features though bringing out detail only hinted at by lower powers. The main nebula centers on the multiple star Trapezium, easily split into its four components, and more magnification reveals a couple of dark lanes and a gaping fish's mouth. The haze of the nebula fades gradually into space on the preceding side, but shows two obvious rays following. Under ideal skies, the rays extend into an enormous, dimly-glowing arc curving southward toward the triple star Iota and then back to rejoin the main nebula's leading edge. Just north of M-42 lies NGC-1977, a faint nebula enveloping a few fairly bright stars.

Remote galaxies present small, hard-to-find, visually unimpressive targets. But the thrill of gazing at light which began its journey when dinosaurs walked upon our planet is ample reward for the search. You can find many of the springtime galaxies with the aid of a good atlas.

Among the most impressive of these galaxies are those you can view simultaneously: M-81 and M-82, or M-65, M-66 and their dim neighbor NGC-3628, for example. Scanning the Virgo cluster only hints at the swarms of galaxies visible with larger apertures, but you'll see most of its Messier and a few of its NGC members.

Large galaxies such as NGC-253 in Sculptor are easy. M-31 spans an entire field which also includes M-32 and NGC-205.

Although small refractors can't provide the brilliant deep sky vistas of larger instruments, it's nice to have one as your second telescope. They combine rugged portability with crisp, sharp images. So dig that old two-point-four out of the attic, fix up the focuser and the mount, and start using it again. It could provide you a lifetime of viewing pleasure.

Ernest Underhay has taught observational astronomy at Santa Barbara City College, written, produced, and given shows at the Gladwin Planetarium, and co-authored a book, Crystals in the Sky, *with Dr. Travis Hudson.*

Photo by Ernest Underhay

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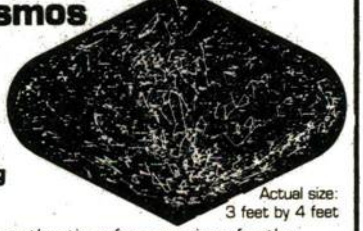

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photography in astronomy

how much sky can my camera capture?

Film formats, effective focal length, and image scale might sound like intimidating technical terms to the beginning astrophotographer. But they're really not that difficult to understand, and it's a good idea to find out what they mean before you try your hand at astrophotography. With a little brushing up on your math, and a working knowledge of photographic terminology, you'll save precious hours of observing and spare yourself the fiscal heartbreak of ruined film. You just can't break the laws of physics and force-fit the entire span of the Milky Way into a 24 x 36mm frame format with a 50mm lens.

No matter what kind of camera you use in taking celestial pictures, you'll be restricted to using the size film that fits in it. And of course, the different techniques that you use to photograph the Moon and planets, nebulae, and star fields all have an effect on the size of your target on the film. To determine how large an object will be on the finished negative or slide use this formula:

$$S = \frac{A \times F}{57.3}$$

where S is the size on film, A is the object's angular size in degrees, and F is the focal length of the lens.

Say you're taking a picture of the Moon with a 300mm telephoto on 35mm film. The Moon's angular diameter is 0.5°. You can look that up in any reference book. So we get: *0.5 x 300/57.3 = 2.6mm in diameter* — that's how big the image of the Moon will be on the negative. Of course, you can substitute any focal length in the equation to give you the proper result for your own photographic system — even if your "telephoto lens" is a 6-inch reflector.

If you think that the lens you want to use for photographing a certain area of the sky, say the North America Nebula (NGC-7000), will give too much magnification, and will chop off part of that deep sky object, you can make a quick check to insure that it will fit in the frame. Use this formula:

$$A = 57.3 \times \left(\frac{\text{frame size}}{F} \right)$$

With a 35mm camera the frame size is 24mm x 36mm.

Now, say you want to take a piggyback photo of the North America Nebula with a 200mm lens. Will it fit? For the vertical coverage divide 57.3 by 200mm, then multiply that by 24mm. That gives you 6.9° of coverage in the vertical axis.

Angular Fields of Lenses for 35mm Format

Focal Length	24mm Dimension	36mm Dimension
18mm	76°	115°
28	49°	74°
35	39°	59°
50	28°	41°
85	16°	24°
105	13°	20°
135	10°	15°
150	9.2°	13.8°
200	6.9°	10.3°
250	5.6°	8.3°
300	4.6°	6.9°
400	3.4°	5.2°
500	2.8°	4.1°

For the horizontal coverage use the same equation — 57.3/200mm x 36mm = 10.3°. So you have a total sky area measuring 6.9° x 10.3° that fits in the field of your 200mm telephoto. Now look up the angular size of NGC-7000 — it's 100'x120', or 1°40' by 2°. That's small enough to fit in the field of your 200mm telephoto with plenty of room to spare.

Whatever type of telescope system you have, you can always figure out whether the object you're trying to photograph will fit onto the film. If you're taking high-resolution photos through your telescope with a projecting eyepiece, however, you'll need to find the focal length of the entire system — its effective focal length. Make sure you include all the optical elements.

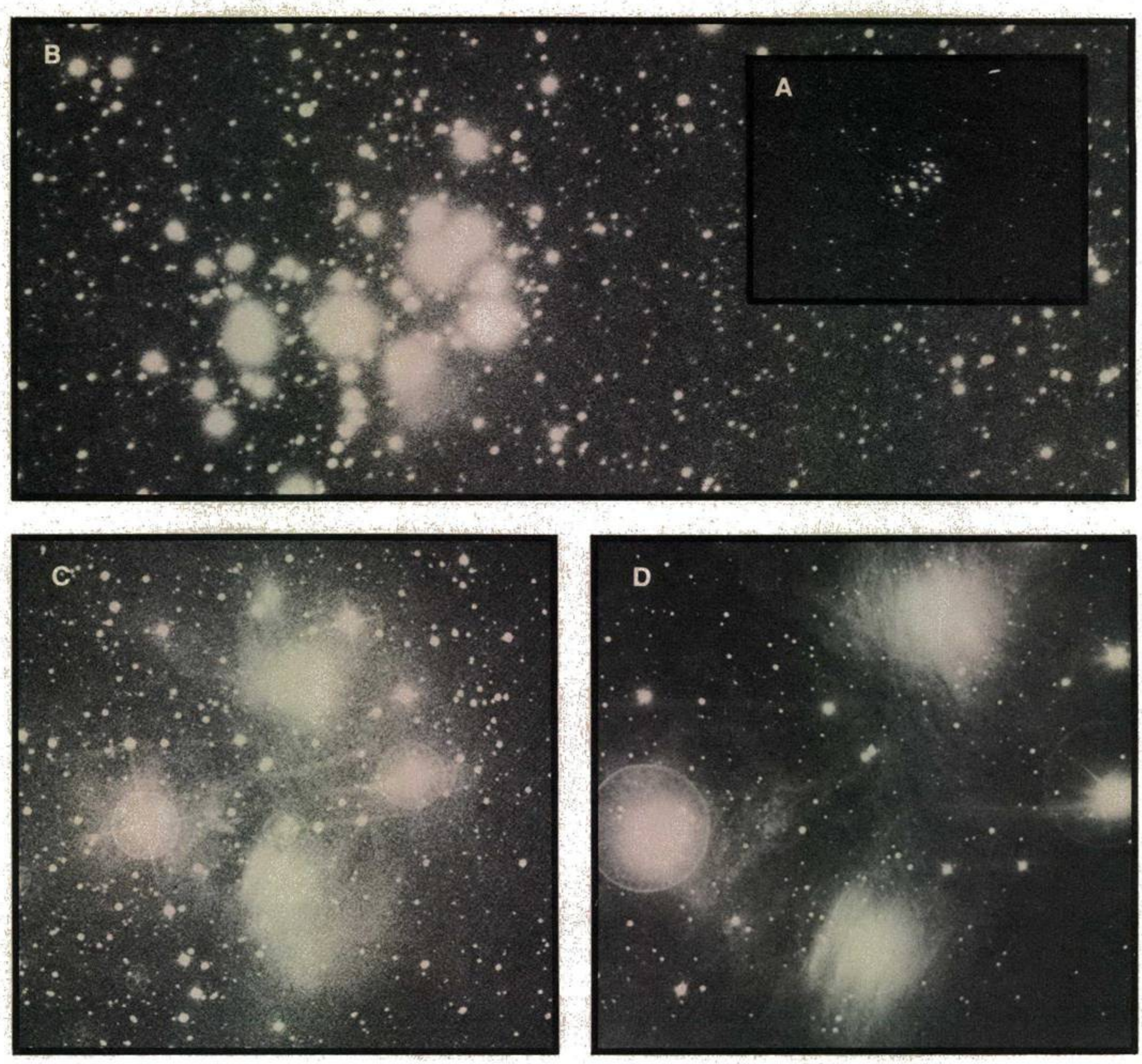
When you use an ordinary photographic lens, the effective focal length is the same as what the lens barrel indicates: 300mm, as in our telephoto lens example, or 50mm, say, for your "normal" lens. The situation gets a little more complicated when you add on a telescope.

Removing the lens and coupling the camera body to a telescope makes the telescope act as the camera lens. The EFL is simply the telescope's focal length. You will usually find this either on the manufacturer's nameplate or in the specifications for the system. For example, a 6-inch f/8 reflector has an aperture of 6 inches, or 152 millimeters. The notation "f/8" means that its focal length is eight times the aperture — 48", or 1220 millimeters. Now that's quite a lens!

When you use an eyepiece to project the telescope's image into the camera, you increase the telescope's focal length by a magnification (M) factor which depends on the focal length of the eyepiece and the distance it projects the image. Work it out as follows:

$$M = \left(\frac{D}{\text{eyepiece f.l.}} \right) - 1$$

D is the distance from the center of the eyepiece to the camera's focal plane. Be sure to keep your units equal: if the eyepiece focal length is in millimeters, you must also measure D in millimeters. If you use a Barlow lens,



These four photos of the Pleiades show the different effects produced by varied film formats and lenses. The first photo (A) was taken by Andrew Grant through a 45mm lens on 35mm Tri-X film with a 15-second exposure. As calculated by the formula in this article, the image of the Pleiades on the negative was 1.2mm. Moving up in magnification, David Healy used a 200mm f/3.5 lens for his 24-minute exposure on 103a-F film (B). The image size on the negative was 1.5° x 200 = 300/57.3 = 5.2mm. Of course, he enlarged it for the print. Photo C by Frank Melsheimer is a 15-minute exposure on 103a-F plate film taken with an 8-inch f/3 Schmidt Newtonian. The focal length in millimeters is 8 x 3 x 25.4 = 610mm. Plug that into the formula and you get an image of the Pleiades 16mm across on the 103a-F plate. Photo D by Martin Germano was taken with an 8-inch f/5, so the image, before enlargement, was 27mm across.

calculate M the same way, but drop the minus sign in the answer.

The effective focal length — or focal length of the telescope and eyepiece acting together as a system — is the focal length of the telescope times the M factor you just calculated:

$$\mathbf{EFL = f.l. \times M}$$

If your rig is set up according to the "afocal" method — where the camera lens looks into the telescope-and-eyepiece — M is calculated by:

$$M = \frac{\textbf{camera lens f.l.}}{\textbf{eyepiece f.l.}}$$

Again, remember to use the same unit of measurement. This gives you the EFL of your optical system.

Now, to apply the EFL to finding the size of the image, let's go back to our basic image-size equation:

$$S = \frac{\mathbf{A \times EFL}}{\mathbf{K}}$$

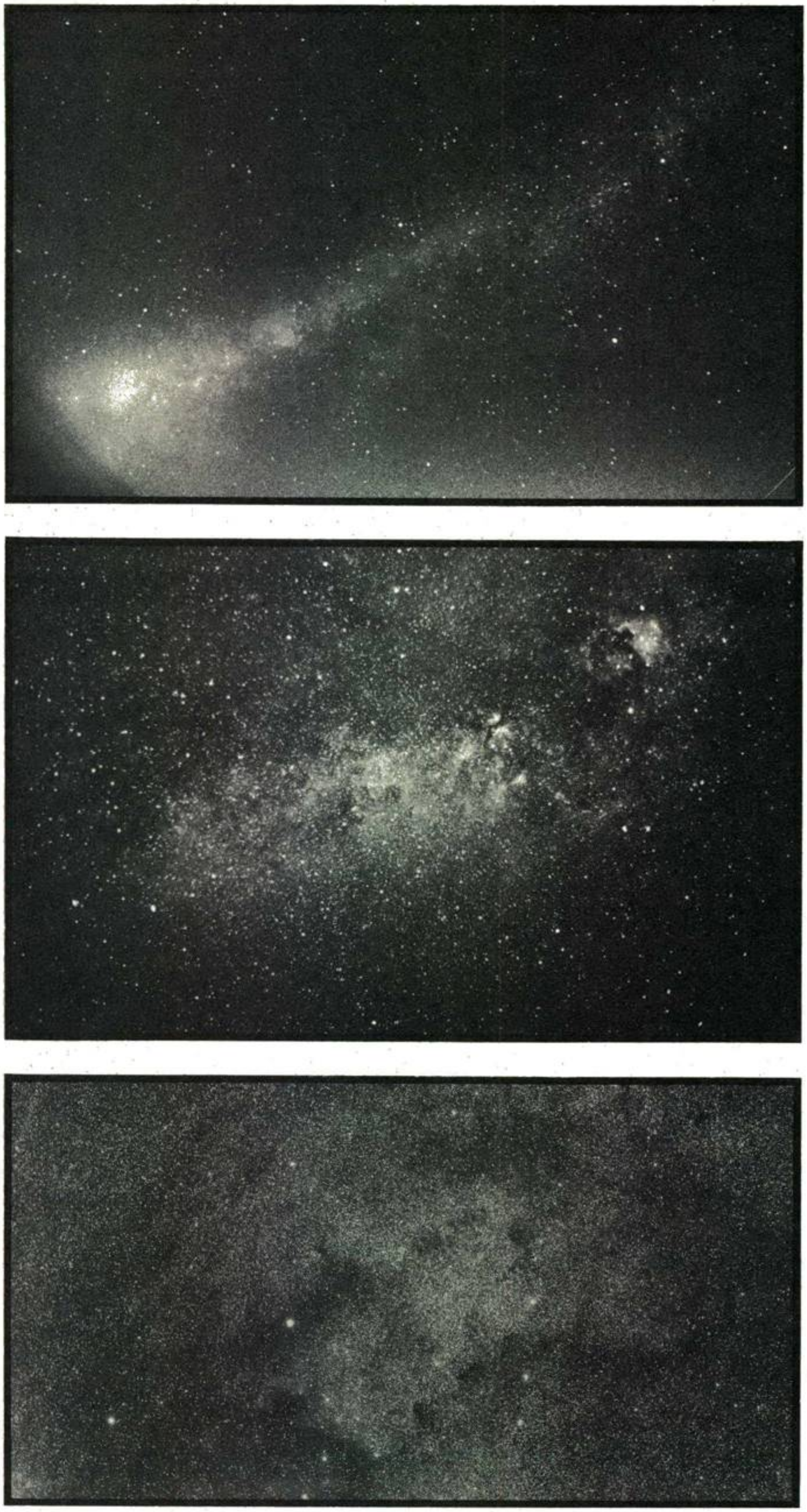
Note that it's a little different now. The angular size is still A, but it need not be degrees. EFL is the effective focal length, and K is a constant. If you want the angle to be in degrees, K = 57.3. If you want it in minutes of arc, use 3438. For seconds of arc, use 206,265. The size will come out in the same units you use for focal length.

Let's try an example: How big will Saturn be at the focus of a 7-inch f/12 telescope? The focal length is 84", and Saturn's rings currently spread about 40 seconds of arc across, so use 206,265 for the constant:

$$S = \frac{\mathbf{A \times EFL}}{\mathbf{206{,}265}}$$

With these values, the answer works out to 0.016 inch — since the focal length is in inches.

An image 0.016 inch across isn't very big. This tips you off that you'd better



Different combinations of lenses and film sizes created these contrasting views of the Milky Way. Top photo by William Hartmann and Michael Morrow covers a 140° expanse of our Galaxy. A 15mm f/2.8 fisheye lens and a 21-minute exposure on Kodak 2475 film recorded not only the central region of Sagittarius, but also the starclouds in Cygnus. Jack Marling (middle) chose to zoom in on the Cygnus star clouds in his 20-minute exposure with a 50mm f/1.8 lens and 2415 film. Although both photos are taken on 35mm film, the difference in lens focal length dictated the degree of sky coverage. Forsaking 35mm film for the improved resolution of 4" x 5" plates (bottom), Ronald Royer photographed the Milky Way area surrounding the North America Nebula (NGC-7000) with a 4-inch f/6 astrograph and a 21-minute exposure.

try eyepiece projection. A 5x magnification by eyepiece projection and a further 10x enlargement in the darkroom will give you a picture of Saturn about ⅞" from ring-tip to ring-tip: small, but not too grainy.

If you want to know what EFL you'd need to make the Dumbbell Nebula fill the frame of your 35mm camera, consider this: The Dumbbell has a diameter of about 8 minutes of arc, and we'll take 24mm as the "frame-filling" size of a 35mm negative. When we rewrite our equation and solve it for the EFL, it comes out as follows:

$$\mathrm{EFL} = \frac{3438 \times S}{A}$$

In this case, we are working in minutes of arc. The numbers work out to 10,314mm — or an EFL of more than 10 meters. Unless you're working with a big telescope, such as those on Kitt Peak, you can't get a focal length this long without magnification.

If you use eyepiece projection on deep-sky objects, the image becomes bigger all right, but it also gets too dim to photograph in a reasonable length of time. What's the solution? Settle for a smaller image on film — say about 5 millimeters across — and enlarge it in your darkroom. Five millimeters is the typical size produced by an 8-inch f/10 Schmidt-Cassegrain with a 2-meter focal length.

Although most astrophotographers today work with the 35mm format, a larger negative offers certain advantages. Say you're making photographs of the Milky Way, and you want to cover a pretty wide field and not have to contend with film grain. Just use a big format film and a big lens. All you have to do to adapt to this larger format is convert 8"x10" into millimeters and then plug it into the same formula we used for NGC-7000.

Astrophotographers sometimes use Metrogon lenses that were used for aerial mapping in WWII. These have a 153mm focal length, work at f/6.3, and cover 90° of the sky on a 9"x9" format, or an 8"x10" if you don't mind losing a little of the corners. How can a lens cover a film this big? That's the way it was designed. Once you're out of the realm of the 35mm format, you have access to a lot of special purpose optics.

What good are all these formulae for focal lengths and angles? Well, they mean you'll never have to guess what your finished photo will look like. Depending on your camera and the film size, you can calculate the size of the finished image long before you actually go outside and start the exposure. And remember, math isn't scary; just warm up that pocket calculator and don't make any silly mistakes like not carrying the decimal.

— *Berry Brunk and Robert Burnham*

ASTRONOMY's Starry Sky Poster

The Starry Sky poster blends the beauty of the heavens with the history of astronomy.

The top half shows the complete night sky from mid-northern latitudes — 6500 stars, plus galaxies, planetary nebulae, Messier objects, and the bright path of the Milky Way. Constellations are outlined for easy identification.

Below this starry expanse is a capsule history of the telescopes that have guided astronomy from the 1600s to the future. Galileo's 2-inch window on the solar system, Hevelius's long refractors, the Hale 200-inch — all the way to the MMT and the Space Telescope. Eleven telescopes in all — each one illustrated and accompanied by a brief history of its accomplishments.

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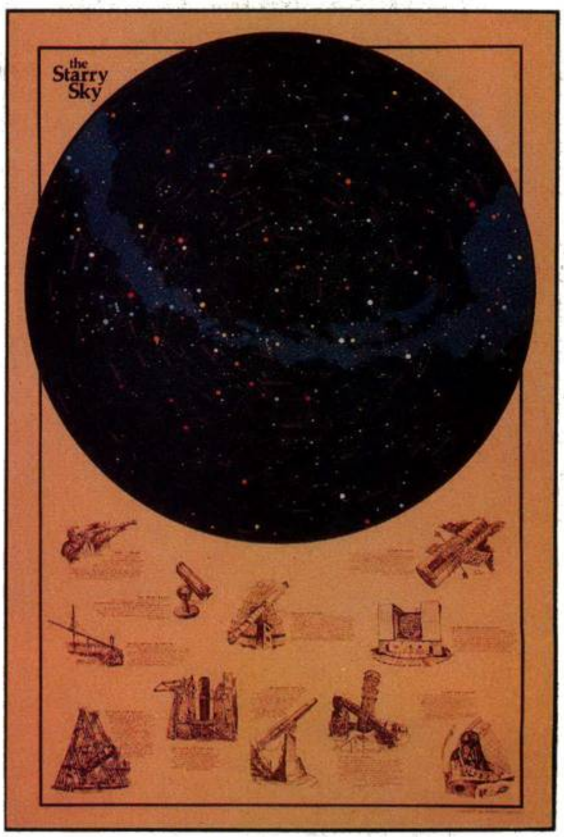

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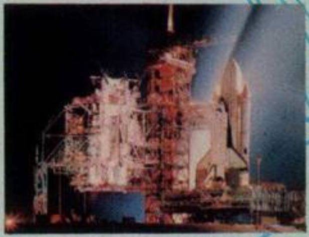

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Viewing and Characteristics

When the Celestron 8 was first introduced, it caused more than a slight stir among serious amateur astronomers, astrophotographers and astronomy educators. Here, at last, was a large-aperture telescope designed for a modern age: it was really portable, easy-to-use and incredibly versatile. Today, the Celestron 8 is the world's best-selling 8-inch telescope.

Though it tips the scales at only 21 pounds and takes up less room than a suitcase, this 480X telescope more than delivers the optical performance so essential to the serious amateur or research scientist. And not only is the C8 the superior astronomical instrument its reputation suggests; remember also that every Celestron Schmidt-Cassegrain can be used as a powerful spotting scope for terrestrial observations and, when coupled to your camera, is a super telephoto lens (2000mm or 40X!).

With this instrument, the very textures of ordinary everyday objects stand out in bold relief, and their images are so brilliant — even in shadow — that high powers, completely beyond the capability of typical terrestrial spotting scopes, may be used routinely. Few people can look through a Celestron 8 for the first time and resist an exclamation of admiration for the optical quality of the instrument.

As an astronomical telescope the Celestron 8 frees you from the Earth's unyielding gravity so that you may freely roam the vast reaches of the solar system.

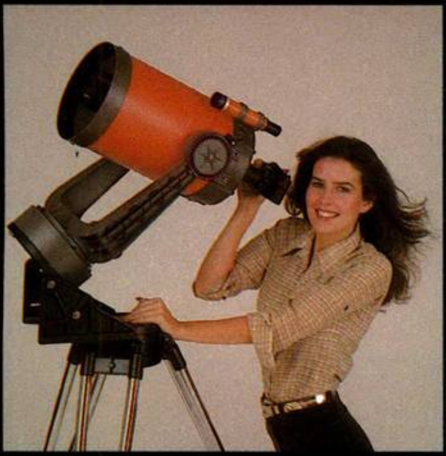
Well within the capability of the C8 are detailed observations of sunspot structure, the solar transits of Mercury or Venus, and a complete hierarchy of lunar craters.

Through the C8 under good seeing conditions the cloud belts of Jupiter appear discontinuous, composed of a multitude of streamers and festoons — and at this aperture the oranges, the reds and the browns of the Jovian clouds are revealed. Further, the moons of Jupiter now appear as disks and can be followed across the entire face of the planet.

With the C8, Saturn's rings are marvelously detailed. The main division (Cassini's division) is instantly obvious even at low power; the innermost (crepe) ring has a distinctly rosy appearance even against the background of space; and there is a noticeable brightening of inner Ring B, as well as a pronounced darkening of outer Ring A. Also visible through the C8 are at least two cloud belts and six of the planet's moons. Through the C8, even tiny Mars (with about half the diameter of Earth) is surprisingly detailed — especially during favorable oppositions. Then such surface features as Syrtis Major and Mare Erythraeum appear discontinuous, the clouds of the planet are visible and the facing polar cap as well as its melt band can be seen.

Under dark skies, the Celestron 8 brings its enormous light-gathering power and resolution to bear for the deep-sky observer. With more than 700 times the light-gathering power of the human eye, the C8 presents star clusters, nebulae and even galaxies in intricate detail. At this aperture, for example, the translucence that characterizes the planetary nebulae begins to emerge and globular clusters are resolved to the core.

Within visual reach of the Celestron 8 are such open clusters as the Pleiades or M35, such globular clusters as M13 or M3, such emission nebulae as the Orion Nebula or the Trifid Nebula, such planetary nebulae as the Dumbbell Nebula or the Ring Nebula, and such galaxies as the Whirlpool Galaxy or M33.



The C8 instrument on wedge and tripod.

For photography, convenient adaptors — available optionally — attach your 35mm SLR camera body or body-plus-lens to the Celestron 8 instantly, permitting telephotography, long-distance macrophotography, full-disk lunar or solar photography, close-up lunar or solar photography, planetary photography, basic deep-sky photography and constellation photography. Completely fills 35mm format.

The Celestron 8 is also capable of much, much more. In fact, with accessories, the C8 is capable of taking its owner to the very frontiers of contemporary deep-sky photography.

With the Celestron 8 as a central instrumental component, you will be able to duplicate on a smaller scale some of the most advanced photographic techniques practiced at the major observatories.

WHY THE CELESTRON 8?

The Celestron 8 is big where it's vital for high performance of its optical system, and small where it matters for convenience, weight and physical size. If you are serious about entering the hobby of astronomy or if you wish to graduate from a smaller telescope, the Celestron 8 can provide an answer to your needs, as it has for thousands of other individuals and schools. When you consider buying a telescope for a lifetime of observing and photography, remember that the C8 has the ability to grow with your interests and that only the Celestron 8 can provide:

- Unexcelled optical quality that Celestron International warrants to be 1/20 wave (peak to peak).
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- Drive system as good or better than competitors.
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- Accessories for nearly every application.

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BASIC C8 SPECIFICATIONS

Optical configuration	Schmidt-Cassegrain
Clear aperture	8 in. (200mm)
Effective focal length	80 in. (2000mm)
Photographic speed (focal ratio)	f/10
Highest useful visual magnification	480x
Near focus (approx.)	25 ft. (7.6m)
Resolution:	
Arc seconds (Dawes' limit)	0.6
Stellar magnitude limit	14
Image scale — degrees per inch	0.72
Film coverage (on 35mm format) at:	
30 feet	4 x 6 in. (0.1 x .15m)
100 feet	1.2 x 1.75 ft. (.36 x .53m)
1000 feet	1 x 17 ft. (.3 x 5.2m)
Secondary obstruction	12% (2¾ in. dia.)
Mounting (equatorial wedge optional)	fork type
Slow motion controls, both axes	manual
Electric clock drive — dual synchronous motors, solar rate	110v, 60Hz, 6 watts
Drive gear diameter	6 in. spur
Polar axis diameter	1⅜ in. tapered
Setting circles	Dec. 4 in., R.A. 8 in.
Optical tube dimensions	9 in. dia., 17 in. long
Optical tube weight	11¼ lbs. (5.1 Kg.)
Telescope size, swung down	9 x 13 x 24 in. (23 x 33 x 61 cm)
Telescope weight — complete	21 lbs. (9.5 Kg.)
Shipping weight	48 lbs. (21.8 Kg.)

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Celestron 8 Astrophotographs

Trifid Nebula M20

Eagle Nebula M16

Globular Cluster M13

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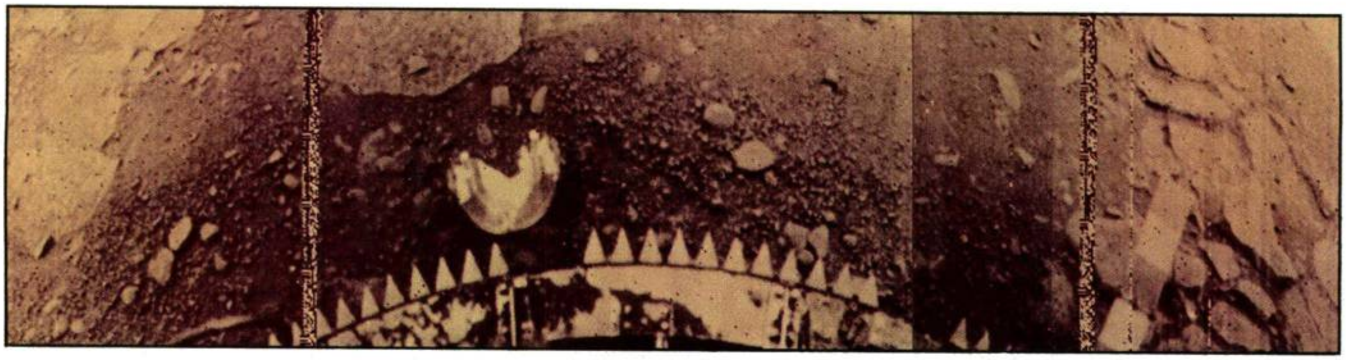
Saturn

Jupiter

Spiral Galaxy M51

ASTRO NEWS



This view returned by Venera 13 shows what looks like an outcropping of flat-bedded rock.

Photos from Tass/Sovfoto.

Soviets Land Venus Probes

Two Soviet spacecraft successfully touched down on the surface of Venus on March 1 and 5, imaged the terrain, and analyzed samples of the venusian soil.

Venera 13 and 14 landed about 2000 kilometers apart on the 900°F surface. Venera 13 returned data for 127 minutes before succumbing to the intense heat and pressure. But before it did, the probe drilled into the brown rocks, brought a sample into the interior of the craft and made measurements of the composition of the soil.

The Soviets relied on surface maps prepared by NASA's Pioneer Venus Orbiter in choosing the landing sites. The first area surrounded a small highland called Phoebe, located southeast of a large shield volcano called Beta Regio. This landing site was the more hazardous of the two.

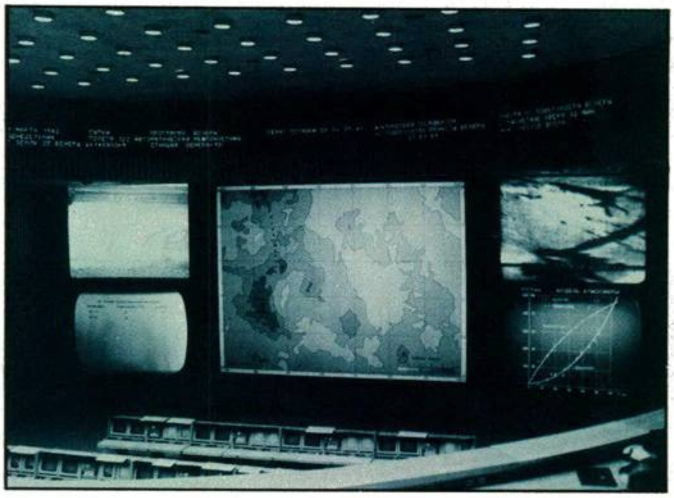
The Venera 14 probe landed in a lowland area that displayed a different type of rock in the transmitted images. No piles of angular stones appeared, although they had in the Venera 13 images.

Venera 14 transmitted data for only 57 minutes, including a color image of the surface. It also performed X-ray fluorescence analysis of the soil. According to the Soviets, the data from the two landers indicate that Venus has a reddish brown or orange sky caused by the reflection of the venusian surface color.

At press time, the Soviets had not released any data from the chemical analysis experiments.

Spacewatch Seeks Funds

Faced with ever-tightening budgets for space related research, many organizations have modified their goals, or completely scrubbed some programs. But Spacewatch — a joint project of NASA and the University of Arizona, geared at building and operating a 72-inch asteroid-searching telescope — has decided to use a time-proven method of obtaining support and funds: advertising. They recently spent part of their remaining budget on a full-page ad in the *Wall Street Journal* soliciting contributions for their research. A variety of donors has expressed interest since the ad appeared, but major financial investors have not surfaced yet.



The monitor inside Soviet "mission control" shows the landing site of the Venera probe.

The Spacewatch telescope would use state-of-the-art computer methods to locate new asteroids and chart their orbits. The University of Arizona has provided a domed building on Kitt Peak, but recent budget cuts have scaled down NASA's contribution.

Today, astronomers locate new asteroids by photographing portions of the sky with a long exposure, then noting the trail produced by the motion of the asteroid against the background of distant stars. About 50 near-Earth asteroids are known, and a continuing search by Eugene Shoemaker and Eleanor Helin, using the 46-cm Schmidt telescope on Mt. Palomar, yields about two new minor planets per year. Other astronomical research throughout the world nets an additional two asteroids per year. Spacewatch should increase this rate 10 to 100 times.

The Spacewatch camera will scan the sky using a charge-coupled device (CCD) in place of a photographic plate. Then the targeted starfield will be recorded by the CCD and stored in the computer. Next, the telescope would rescan the same part of the sky, and the computer would check for points of light which have moved. Creating these complex computer programs is the most difficult challenge of the project.

The Spacewatch camera would search for asteroids during two-thirds of the total monthly dark time. The remaining dark time would be used for basic astronomical research. When the Moon is out, the camera will follow up on newly discovered objects.

Asteroids are important to our future goals in space for many different reasons. Some Earth-approaching asteroids are the easiest solid objects to reach in the solar system. Anteros, a mile wide chunk, is more accessible from Earth than the Moon. NASA estimates that a manned expedition to Anteros would require 23 shuttle launches, though this would represent a major funding and engineering effort.

At present we lack much of the knowledge needed to mine, terraform, or otherwise exploit non-terrestrial resources. And philosophical questions about our right to do so are still hotly debated. Yet many believe that the use of non-terrestrial materials is the key to long term, routine occupation of space.

The water present in asteroids could be converted into hydrogen and oxygen for propellant and breathing. A hydrogen-oxygen powered orbital transfer vehicle could make several hundred round trips between shuttle orbit and geo-stationary orbit using water contained in a 150-foot chunk of carbonaceous asteroid. It's also possible that the platinum group metals contained in asteroidal materials could be exported to Earth and sold — a profitable by-product of space-based industry.

NASA scientists feel that many important cosmological questions will be answered by prospecting the Earth-approaching asteroids. These objects may be left over from the early days of the solar system. Some may come from the asteroid belt. We have virtually no detailed knowledge of the asteroids.

Ground-based observations of asteroids allow scientists to make educated guesses about their composition. Some appear to be mixtures of rock and metal, some

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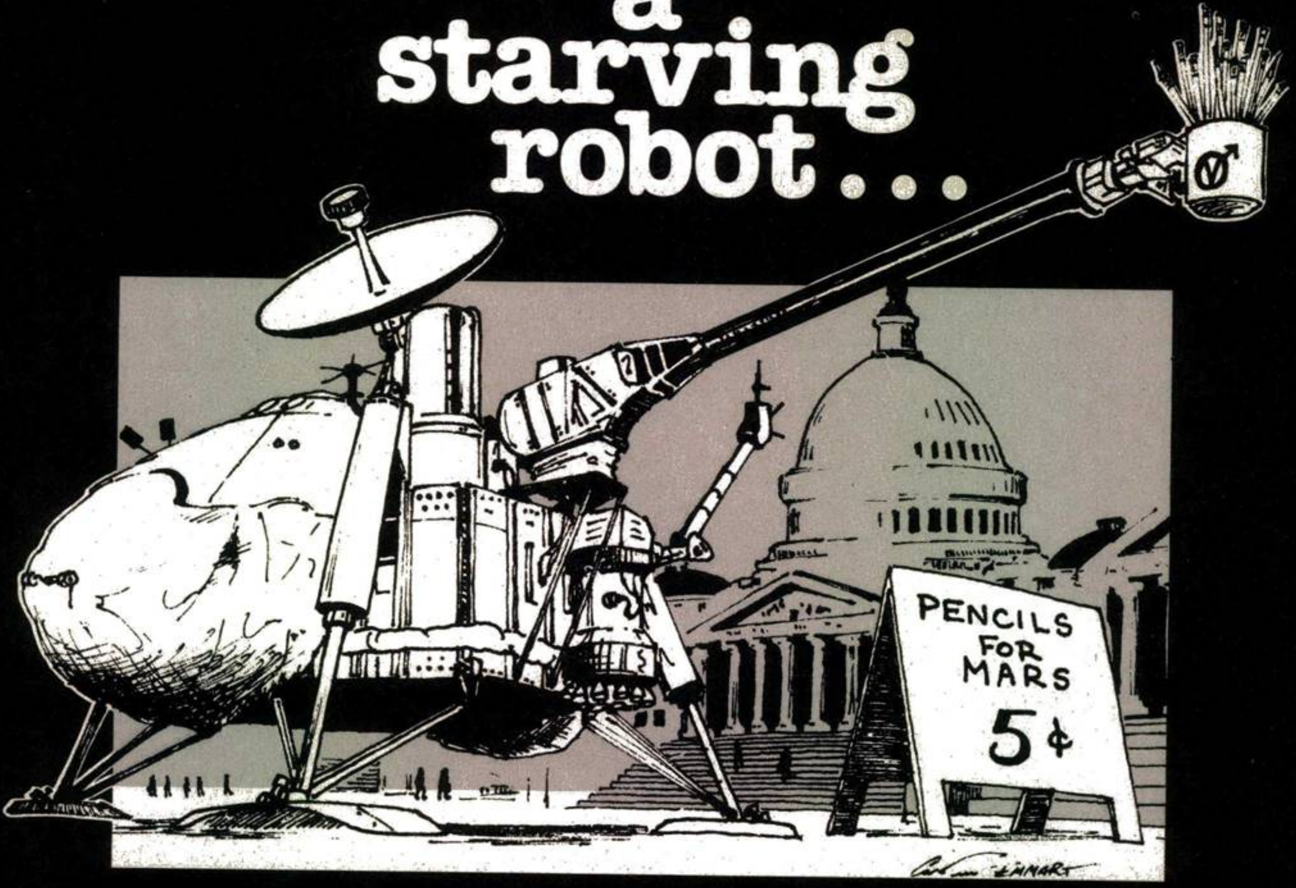

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are carbonaceous, some may be metal, and some are not easily categorized. A single space shuttle flight could launch a probe to Anteros which could return a sample to Earth. A space vehicle propelled by a low-thrust solar electric propulsion system could sample as many as eight different asteroids and return those samples to Earth. This mission could also be started by a single space shuttle launch. The more asteroids we know about, the easier the missions become. Asteroid missions are now planned for the 1990s at the earliest.

Spacewatch will also keep track of bodies which may collide with the Earth. While such an event is extremely unlikely in the near future, it is worthwhile to gather information which may provide a warning. The impact of even a small (100 ft.) piece of asteroid would cause a multi-megaton explosion.

Spacewatch hopes to find and track asteroids with a telescope funded by private sources. Eros photo by Jean Guy Moreau.

In order to begin the Spacewatch asteroid search by 1985, the University of Arizona is asking the general public to contribute directly to the Spacewatch project. Public enthusiasm following the spectacular Voyager reconnaissance of the Saturn system, and the successful space shuttle flights was overwhelming, and Spacewatch hopes a similar enthusiasm will greet their efforts in space. *Stewart Nozette.*

For information on contributing to project Spacewatch, contact:
University of Arizona / Project Spacewatch, Lunar and Planetary Laboratory, University of Arizona, Tucson, AZ 85721.

Third Gravitational Lens Discovered: Astronomers Puzzled

Astronomers have discovered a third gravitational lens, a finding which has them puzzled about why many more of these celestial phenomena have not been reported.

A gravitational lens occurs when light from a distant object is bent as it passes through a strong gravitational field. The bent light, passing through either side of the gravitational source, reaches the observer from two slightly different directions, giving the impression that two objects are being seen. (See "Gravity Lenses," ASTRONOMY, July 1981.)

The first gravitational lens effect, predicted by Einstein in 1936, was discovered in 1979; a second was discovered a year later. The latest gravitational lens was discovered by Dr. Daniel W. Weedman of Pennsylvania State University and a team at the University of Arizona headed by Dr. Ray J. Weymann.

The twin images are in the direction of the constellation Pisces, and lie about 10 billion light-years from Earth. The suspected gravitational lens was discovered on a photographic plate obtained August 2 with the 3.6-meter Canada-France-Hawaii Telescope on Mauna Kea, Hawaii. A confirming plate was obtained September 4 with the 4-meter telescope at Kitt Peak National Observatory in Arizona. On October 30 and 31, astronomers at the University of Arizona-Smithsonian Astrophysical Observatory's Multiple Mirror Telescope established the identity of the two images and determined the distance of the quasar that was being imaged.

To prove conclusively that they have found a third gravitational lens, the astronomers will take very sensitive direct photographs and search for the material that is causing the gravitational deflection between the quasar and Earth. The quasar images have magnitudes of approximately 19.5 and 21.

The scientists reported that survey techniques such as those used to discover this object have found over 1,000 quasars, and they are puzzled as to why so few paired quasars have been found.

NASA — Comet Bound?

Last year, it appeared that American scientists had no hope of exploring a comet in this decade; the Reagan administration let NASA's last-chance plan to fly past Halley's comet pass without even considering it. The space agency would have to watch from the sidelines as the Europeans, Soviets, and Japanese launched their probes to the famous visitor.

Now a group of researchers has proposed sending an aging American satellite on a comet chase. If NASA approves the idea, ISEE 3 (International Sun-Earth Explorers-3) will plunge into the tail of comet Giacobini-Zinner in September 1985. Ironically, the U.S. would be the first to reach a comet. The other nations' craft won't reach Halley until the following March.

The Giacobini-Zinner encounter isn't a shoe-in. The option requires tricky maneuvering and interplanetary flight from a satellite built for more staid purposes. And it faces stiff opposition from researchers who want to keep the craft where it is to continue their studies.

The ISEE satellites are the most sophisticated instruments to investigate the interplay between the solar wind and the Earth's magnetic field. Two of the craft — one American and one European — orbit the Earth to study the magnetosphere. The third craft — an American satellite launched in August 1978 — orbits a spot between our world and the Sun. This location allows ISEE 3 to observe the wind of particles streaming off the Sun as they approach the Earth. It also permits studies of the low-energy cosmic rays our planet's magnetosphere screens out.

ISEE 3 now has been on station almost a year longer than planned, and a group of the craft's scientists feel it's time to pursue new goals. "The spacecraft has been in its present position for 3½ years," says Fred Scarf, principal investigator for the electric and magnetic wave instruments. "In the current location, ISEE 3 has a relatively low priority in NASA's tracking schedule. We'd like to do some exciting new studies."

These researchers want to send the craft on an excursion behind our planet to study the magnetotail and then to make the flight to Giacobini-Zinner. No one objects to the first part; the spacecraft easily could return to the present location from the tail region. But several ISEE experimenters passionately object to the comet option.

Technically, NASA could track the craft up until a year or two after encountering Giacobini-Zinner. During that time, the spacecraft could continue studying the solar wind and cosmic rays. Either way, the satellite would no longer be positioned between the Earth and Sun. Physicists studying the relationship between the solar wind and the terrestrial magnetosphere would lose a valuable monitoring station.

The flight to Giacobini-Zinner wouldn't begin until December 1983 at the earliest. Departure could be delayed another year if NASA wants to keep the craft near home as long as possible. Either way, the comet flyby would occur in September 1985.

At one time, Halley was the preferred target. The chance to explore a second comet, though, clinched it for Giacobini-Zinner. Halley is the only active, fresh comet known that has a predictable orbit. The Europeans, Soviets, and Japanese intend to take the once-in-a-lifetime opportunity to explore it. But while Halley is an exciting target, it's not a typical comet. Halley is young, active, dusty, and bright.

Giacobini-Zinner is closer to the norm than its famous cousin, though it produces a spectacular tail, is brighter than most comets, and spews off dust that is lighter and fluffier than any other comet's. Since it circles the Sun more closely than Halley does, repeated passes through the inner solar system have removed most of Giacobini-Zinner's ice and dust.

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ASTRONEWS

Planetary scientists believe that comets are debris left from the solar system's birth. The geology of the nucleus, the dusty iceberg at the heart of a comet, could show how material in the early solar system came together to form solid bodies. The composition of the gases and dust thrown off the nucleus could reveal the original ingredients of the planets. And the interaction of the solar wind with the gases could unveil new data about plasma physics.

ESA's Giotto spacecraft going to Halley will touch on all three areas. ISEE would examine just the plasmas — it doesn't carry the cameras, spectrometers, and dust instruments needed for a more thorough job. But ISEE could answer questions like these: How fast does the Sun's ultraviolet light strip electrons from the gases and turn them into plasmas? How much plasma is produced? How dense is it at any given spot? What's the composition of the plasmas? How does the solar wind interact with the comet's atmosphere?

Physicists ask similar questions about plasmas anywhere in space, whether they're in Venus' ionosphere or Jupiter's magnetosphere. NASA launched ISEE to learn more about this branch of physics. An encounter with Giacobini-Zinner would extend that goal.

While detailed comet theories abound, they're backed by few hard facts. A spacecraft can collect solid information for a single comet. During 1985 and 1986, the International Halley Watch will use every means it can — from radio telescopes to the Space Telescope — to observe Halley so researchers can compare the data from the spacecraft with their observations of other comets. Many planetologists will be able to test their ideas about these objects for the first time. Additionally, if the Watch could observe another comet — such as Giacobini-Zinner — planetologists would be surer of their ability to apply their conclusions to all these bodies.

NASA managers will have to decide soon whether or not ISEE will provide this data from a second comet. In better times, it could keep ISEE 3 near Earth and have a comet mission, too. As it is, the bitterness of the debate over ISEE's future is a sign of how tight NASA's budget has become. Under these circumstances, the plans for an aging spacecraft take on new importance. *Van R. Kane.*

Pioneer 10 Studies Heliosphere

On March 2, 1982, Pioneer 10 — the first spacecraft to radio images of Jupiter to Earth — marked its tenth anniversary in space. The small probe is now between Uranus and Neptune on its way out of our solar system — the first man-made spacecraft to travel this far.

Pioneer 10 continues to transmit new information and is currently helping astronomers define the extent and behavior of the Sun's atmosphere — the magnetic "bubble" which contains the Sun and the planets. This bubble in the interstellar medium is called the heliosphere.

Scientists await current spacecraft findings "with intense excitement," says James A. Van Allen, University of Iowa, Pioneer 10 experimenter, "because we think the Sun is typical of a majority of the stars in the universe. It's the only star we can measure from close up. Finding the extent and exact mechanisms of the Sun's atmosphere will tell us a great deal about the Sun itself, about the interstellar gas surrounding the solar system, and about stars in general."

The picture now emerging shows that the heliosphere is enormous, far larger than predicted. Pioneer is traveling "down the tail" of the heliosphere tear drop. The spacecraft is seeking the skin of this heliospheric bubble, the boundary between the Sun's atmosphere and true interstellar space. No one knows, but scientists think this boundary may lie between five and 10 billion miles from the Sun.

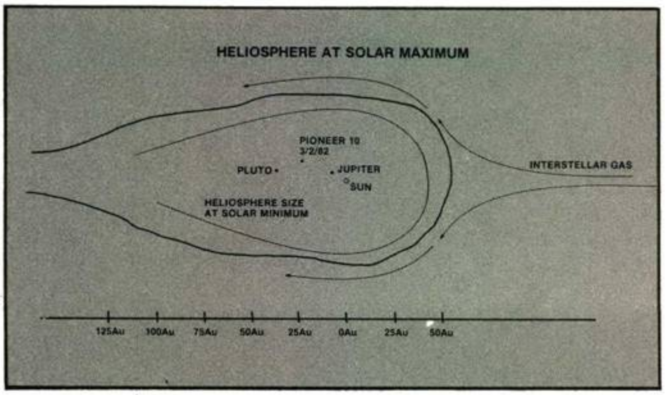
Experts at NASA's Deep Space Network expect to be able to track Pioneer out to somewhere beyond five billion miles.

At the spacecraft's current distance, the Earth would be seen as a pinpoint of light, never more than 2.2° away from a Sun still intensely bright, but no larger than a pinhead. Because of this huge distance and the decline in brightness of the Sun, Pioneer's Sun sensor will not be able to provide the "Sun pulse" for much longer. This reading gives scientists a rotational position of the spinning spacecraft several times a minute. But NASA-Ames mission controllers have devised a method of making star maps with the Pioneer camera, Imaging Photopolarimeter, to provide the needed rotational and attitude data.

"Because of Pioneer's data we now believe the heliosphere bubble breathes in and out once every 11-year solar cycle," says John Simpson, University of Chicago Pioneer experimenter.

The shock waves of the enormous storms on the Sun seem to persist in the heliosphere for as long as a year, probably changing the heliosphere's shape, as if it were a huge pulsating jelly fish.

"It's hard to overstate the interest of the physics coming out of this phase of the Pioneer mission," comments Aaron Barnes, NASA-Ames astrophysicist. "We are constantly entering unexplored territory, and we really don't know what we'll learn about our local star."



Did Tidal Wave Kill Dinosaurs?

A three-mile-high wave of water sweeping around the Earth after a large comet or asteroid hit the ocean 63 million years ago might have been responsible for the sudden extinction of the dinosaurs and other ancient life forms.

This theory, derived from computer models of the effects of meteorite impacts, was presented by Thomas J. Ahrens and John D. O'Keefe of the California Institute of Technology on March 15 at the 13th Lunar and Planetary Science Conference in Houston, Texas.

The scientists based their studies on a theory advanced by Luis and Walter Alvarez of the University of California at Berkeley. The father/son team deduced that a comet or asteroid several miles in diameter caused widespread extinctions at the end of the Cretaceous Period 63 million years ago. (See "The Fallen Sky," ASTRONOMY, April 1982.) In those extinctions, some 90% of the life on Earth — from dinosaurs to ocean-dwelling plankton — perished in a short period of time. The theory stems from the discovery that worldwide layers of 63 million-year-old sedimentary material appears enriched with meteoritic material. Ahrens and O'Keefe assumed that the object may have hit the ocean.

"We studied an ocean impact because it is more likely, since 70 percent of the Earth's surface is ocean," said Dr. Ahrens. "Also, a crater 100 miles in diameter and 63 million years old has not been found.

"The Earth has a way of hiding such scars on the ocean floor, for some 51 percent of the ocean floor that existed 63 million years ago has now been recirculated into the deep-Earth interior by subduction," he said.

Most researchers, including the Alvarez team, have concentrated on the effects of a worldwide dust cloud raised by a meteorite impact as the reason for the dinosaur's extinction. This cloud may have obscured the Sun for many months, destroying much of the planet's plant life and disrupting the food chain.

But the Caltech scientists have raised the possibility that the immense tidal wave from an ocean impact — rather than the impact itself — may have been the prime contributor to the extinctions. In their computer calculations, they assumed a seven-mile-diameter object — the size calculated from the meteoritic enrichment of the worldwide sedimentary deposits. The impact would have released

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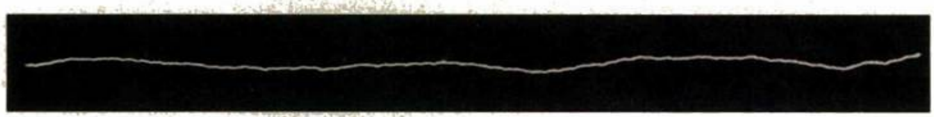

FIGURE 1: C8-S/N813888 DRIVE TEST

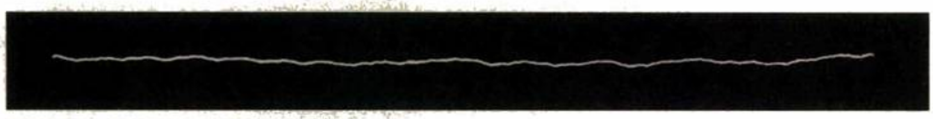

FIGURE 2: C8-S/N811280 DRIVE TEST

Figures 1 and 2 above are average results of drive tests of Celestron 8 telescopes. They were made by deliberately misaligning the polar axis of the telescope by a fixed offset from the celestial pole. Specifically, the setting circles were used to cause the polar axis to point 10 degrees west of the celestial pole. Then, with the telescope stopped down to about f/50, a star of fourth or fifth magnitude located near the celestial equator and near the meridian was photographed for 15 minutes. The resulting star trails shown above can be analyzed for magnitude and rate of any tracking errors of the drive system. By inspecting these figures and figure 3, it can be easily shown that any drive system errors can be overcome during deep-sky photography by using a drive corrector.

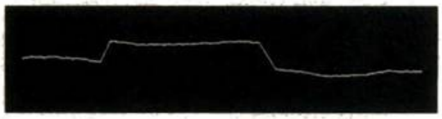

FIGURE 3

Figure 3. — Star trails photographed using the same procedure as above, but using a drive corrector as the 60 hz. source for a Celestron 8. At 3 minutes into the test, the slow button was depressed and held for 12 seconds. Then, at 8 minutes into the test, the fast button was depressed and held for 12 seconds. Note that the tracking error introduced by the drive corrector buttons exceed the errors in the drive itself by at least a factor of two. We are simply demonstrating in this photograph that a standard drive corrector has more than enough overriding capacity to offset any clock drive error that could affect a long exposure astrophotograph.

A telescope clock drive is provided so that the instrument will automatically rotate about its polar axis to counter the rotation of the Earth on its axis. This causes a star field to remain fixed in the field of view of the instrument. Consider that if you were viewing Jupiter at 450 power without a clock drive; the image would traverse from the center to the edge of the field of the ocular in only 10 seconds of time.

How accurate must the clock drive system of a telescope be? How do you evaluate the accuracy of such a system? Certainly if the image appears stationary in a high power ocular, the drive system is adequate for visual work. On the other hand, if you are using the telescope to take guided deep-sky photographs, and if you can keep a guide star centered on the cross hairs of a high power guiding eyepiece, the drive system is adequate for this purpose.

The photographs here document an evaluation of the clock drive accuracy of the average Celestron 8 Schmidt-Cassegrain telescope. The procedure used was as follows: The declination setting circle was used to set the polar axis of the telescope under test so that it pointed 10 degrees west of the celestial pole. A 4th or 5th magnitude star near the celestial equator and the meridian was photographed for 15 minutes. The resulting trail on the film is a north-south line about one inch long (at the 80-inch e.f.l. of the Celestron 8). Variation from a straight line of this star trail can be evaluated for change in clock drive speed and duration of these changes.

As you can see, these telescopes each exhibit some clock drive errors as any commercial telescope will. For deep-sky astrophotography in any commercial telescope, you must use a drive corrector to control clock drive error. Celestron does not wish to imply that deep-sky astrophotography is an effortless task; it is a learned skill, an art as much as a process; the more you practice, the better your results.

Without evaluating the underlying facts, an astrophotographer might automatically specify a worm gear for the clock drive of a telescope. This as opposed to a dual-spur gear drive such as used in the Celestron 8. If a worm-gear drive is to present any improvement over the spur gear drive, the worm wheel itself should be fully generated by multiple pass hobbing, and the worm must be precision lapped. However, this is just the beginning. It is not the run out of the worm in the case of the worm drive or the one-hour rotation period of the pinion gear of the Celestron 8 drive which could introduce drive fluctuations which might be difficult to guide out with the drive corrector. It is the higher speed reduction gears in the drive motors, which if other than perfect, create small but rapid variations in the drive speed. If inexpensive timing motors are used in conjunction with a worm drive, these high speed variations will be introduced by the spur gears in its reduction train. The Celestron 8 and competitive units use timing motors with spur-gear speed reducers. In the case of the Celestron 8, however, two motors are used which drive at opposite diameters to the main drive gear. This, in effect, loads one motor against the other to dampen high-speed gear variations.

The adequacy of the drive system of the Celestron 8 is attested to by the multitude of photographs that have been submitted by Celestron owners and published in the various journals. Of course, you can purchase a separate worm drive system for the Celestron 8. We consider that only those which cost several hundred or even thousands of dollars offer sufficient precision to yield any improvement over the standard Celestron 8 drive.

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"We calculate that four seconds after a 25-mile-per-second impact with a four-mile-deep ocean area, a cavity containing superheated water and vaporized rock 25 miles wide and 20 miles deep would appear," said Dr. Ahrens. "A 30-mile diameter steam bubble, extending some 25 miles into the atmosphere, would cover this transient crater.

"From the transient cavity a tidal wave about three miles high would envelop the entire Earth in 27 hours. In deep oceans, this tidal wave would still be 500 feet high after traveling halfway around the Earth.

"We conjecture that, since the Earth at that time had little or no ice in the polar caps, about 25% of what is now land was submerged by shallow inland seas connected to the oceans. Paleontologists describe a typical dinosaur habitat as marshy areas around these seas, with enough vegetation to support the food chain.

"A large tidal wave running onto such marshland would have caused extensive stripping and silting-over of vegetation, destroying the food chain for all large land animals," said Dr. Ahrens. A tidal wave would result even if the meteorite hit land, according to the scientists, because the resulting quake — measuring 12 on today's Richter scale — would create an immense seismic sea wave.

The researchers found that an ocean impact would also create a worldwide atmospheric dust layer, 10 to 100 times the mass of the meteorite. The material ejected immediately upon impact would be largely from the meteorite — the material that settled out to create the meteoritic sediment layer.

Besides their studies of the effects of an ocean impact, the Caltech geophysicists also modeled how such a large meteorite would have interacted with the Earth's atmosphere. The incoming meteorite would have little effect on the atmosphere, but, once the object hit, vapor and molten material would blow a hole in the atmosphere. This hole would be filled rapidly by an inward and upward rush of air that would entrain the material and loft it high into the stratosphere where it would be distributed worldwide by air currents.

The scientists calculated that about 15% of the impact energy would be transferred to the atmosphere, raising the global temperature by 10° C in a matter of hours. Some paleontologists suggest that this rapid temperature rise would have been followed by a rapid drop, as the meteoritic dust obscured the Sun.

Their computer model studies have led Ahrens and O'Keefe to suggest a number of further avenues for research: "A magnitude 12 earthquake would have produced both landslides on land and marine mudflows on the continental shelves, and we are troubled by the lack of evidence for such disturbances in the sediments studies to date," said Dr. Ahrens. "We suggest that searches for these phenomena be made in the localities of 63 million-year-old boundary layers.

"We also haven't examined in detail the effects of injecting huge amounts of water into the atmosphere along with the dust which would have occurred in an ocean impact. It may be that this water quickly rained out, carrying the dust with it."

ASTRO CALENDAR

May 22.	**36th Annual Convention of the Astronomical League's North Central Region.** Carroll College, Waukesha, Wisconsin. Contact: Milwaukee Astronomical Society, William Konig, P.O. Box 275, Mequon, Wisconsin 53092.
May 26-28.	**Big Bear IAPPP Symposium.** Camp Oaks, Big Bear, California, just prior to Riverside TMC. Contact J.L. Hopkins, 7812 W. Clayton Dr., Phoenix, AZ 85033.
May 26-30.	**Amateur Astronomy and Telescope Making Conference** sponsored by the Astronomical League's S.W. Region. Fort Davis, Texas. Contact: George Ellis, 7117 Misty Meadows Dr. S., Fort Worth, TX 76133.
May 28-31.	**Riverside Telescope Maker's Conference.** Big Bear, California. Contact: Cliff Holmes, 8642 Wells Avenue, Riverside, CA 92505.
June 9-12.	**Southeastern Planetarium Association (SEPA) Annual Meeting.** Bays Mountain Planetarium, Kingsport, Tennessee. Contact: Mike Chesman, Bays Mountain Planetarium, Route 4, Kingsport, TN 37660.
June 10-11.	**3rd Annual Dayton IAPPP Symposium.** Fairborn, (Dayton) Ohio. Contact: R. Genet, Fairborn Observatory, 1247 Folk Rd., Fairborn, OH 45324.
June 11-12.	**12th Annual Apollo Rendezvous and Telescope Fair.** Dayton, Ohio. Contact: Coordinators, Apollo Rendezvous, 2629 Ridge Avenue, Dayton, OH 45414.
June 26-July 1.	**93rd Annual Meeting of the Astronomical Society of the Pacific.** University of California, San Diego — La Jolla, California. Send SASE to: San Diego Meeting, A.S.P., 1290 24th Avenue, San Francisco, CA 94122.
July 16-24.	**National Spaceweek.** Needs local organizers. Contact: Spaceweek National Headquarters, P.O. Box 58172, Houston, TX 77058.
July 16-24.	**Florida Spaceweek '82.** Various cities. Contact: Florida Spaceweek Committee, 993 Macco Road, Cocoa, FL 32922.
July 18-August 8.	**International Workshop for Amateur Astronomers** (I.W.A.A.). Havelte, The Netherlands. Contact: Niels van Weersen, Sand-Ambachstraat 17, 2691 BL 's Gravenzande, The Netherlands.
July 21.	**24th Annual Summer Science Program in Astronomy.** Ojai, California. Contact: Roger D. Klauscer, Thacher School, Ojai, CA 93023.
July 21-24.	**ALCON '82** — national convention of the Astronomical League including ALPO, IAPPP, IOTA and National Deep Sky Observers annual meetings. Peoria, Illinois. Contact: ALCON '82, P.O. Box 5203, Peoria, IL 61601.
August 11-12.	**IAPPP Springfield Meeting.** Hartness House, Springfield, Vermont. Contact: R.C. Wolpert, 144 Neptune Ave., N. Babylon, NY 11704.
August 14-17.	**Stellafane.** Springfield, Vermont. Contact: Dennis di Cicco, 60 Victoria Road, Sudbury, MA 01776.
August 17-26.	**XVIII General Assembly of the International Astronomical Union** (professional meeting). University of Patras, Greece. Contact: Organizing Committee, General Assembly IAU, University of Patras, Patras, Greece.

An open letter to Meade and Celestron owners from the President of Meade Instruments Corporation

Recently, advertising by Celestron International has appeared in this magazine which we believe has led to confusion and dismay among Meade and Celestron owners. While it is not normally the Meade way to answer such advertisements, we feel an obligation to the thousands of Meade Schmidt-Cassegrain owners to set the record straight.

1. **The Advantage of an Oversize Primary Mirror in a Schmidt-Cassegrain (SC) Telescope.** Celestron states that an 8″ primary mirror oversized by only .008″ in radius is sufficient to catch outer light rays deflected through the SC corrector plate on their way to the primary mirror. This analysis is correct **for light parallel to the telescope's optical axis,** i.e., for light imaged precisely in the center of the telescopic field. For light rays imaged ½° off-axis, i.e., rays imaged near the edge of the field of view, a simple mathematical analysis* proves unequivocally that, apart from baffling, **the primary mirror in an 8″ SC telescope must be 8.218″ diameter, in order for these off-axis rays to be imaged fully.** Celestron ignores these off-axis rays completely in their oversize-primary analysis.

   Fig. 1 demonstrates the above statement: The on-axis ray (1), which is imaged at the center of an SC telescope's field of view, is deflected .008″ by the corrector plate, and only a slightly larger primary mirror of 8.016″ diameter is indeed required to image this ray at the focal plane. But ray (2), which is ½° off-axis, and which is imaged near the edge of the telescopic field, requires an 8.218″-diameter primary in order to be imaged at all. The Celestron C-8, with its 8.060″ primary mirror, does not image this ray, while the Meade 2080, with its 8.250″ primary, does. The result is significantly brighter (about 10% brighter) off-center images in the 2080 than in the C-8.

2. **Image Brightness.** Celestron's own graph, reproduced here as Fig. 2, attests to the superior image brightness in the Meade 2080, as compared to the Celestron C-8 and Dynamax-8 telescopes. Note from Fig. 2 that the C-8's image brightness falls off rapidly for light rays more than 0.2° away from the center of the telescopic field. In fact, surprisingly, Celestron admits in this graph that the **Meade 2080's image brightness is uniformly greater than the C-8, for star images located between 0.2° and 0.6°** from the center of the field, **an area comprising more than 65% of the total telescopic field.** Over the other 35% of the field, image brightness is the same in both telescopes. (For reference, the actual radius of the field of view at the Cassegrain focus in both the 2080 and C-8 is about 0.7°.) In fact, because of its smaller primary and secondary mirrors, and because of its light baffle design (see below), **the C-8 is operating as a 7.59″-aperture telescope of 2080-type design, for a star located 0.3° off-axis** (i.e. about half-way from center-to-edge of the field). Equivalently, **it would require a Schmidt-Cassegrain telescope of 8.39″-aperture of the C-8 design to duplicate the off-axis image brightness of the Meade 2080.** The C-8 **with** high transmission coatings does not yield off-center images as bright as the Meade 2080 **without** coatings.

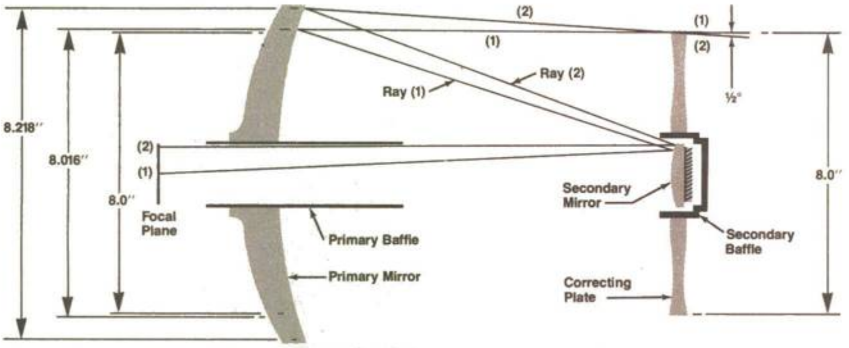


Fig. 1: Optical Design of the Meade 2080 (Drawn not to scale for clarity.)

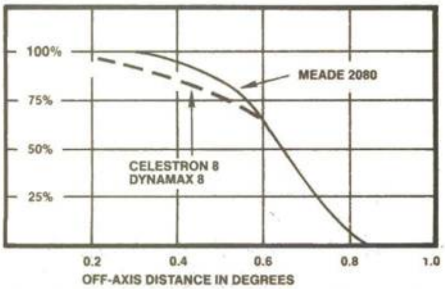


Fig. 2: Off-Axis Field Illumination. The vertical axis represents image brightness, expressed as % of maximum illumination. This graph, produced by Celestron, confirms the Meade 2080's superior field illumination over both the Celestron C-8 and Dynamax-8.

3. **Light Baffles.** An oversize primary in an SC telescope is of no advantage, however, if the internal light baffles are not designed to take advantage of this fact. Simply increasing the primary mirror diameter of the C-8, for example, will result only in marginally increased image brightness, because the C-8's light baffles preclude most of the additional light ever reaching the focal plane. In the Meade 2080 the primary and secondary mirror diameters, and the baffle dimensions, were computer optimized **as a system** to produce the additional image brightness confirmed by Celestron's own tests.

4. **The Absence of Stray Light in 35mm Photos Through the Meade 2080.** Using an oversize-format camera for which the 2080 was not designed and, we believe, by significantly overexposing the photo, Celestron in their ad was able to show a halo outside the 2080's field of view. This halo is not in any way the result of the opaquing of the baffle tubes. In fact, it is precisely because the 2080 was designed to optimize 35mm film illumination that unshielded light reaches only outside the field of view, as it should. Halos are never present in 35mm photos through the 2080, and images, with proper exposure times, are of extremely high contrast.

The Celestron C-8 was designed in the 1960's, and has remained essentially unchanged in optical design since that time. It remains a fine example of the technology of the 1960's. The Meade 2080 incorporates recent computer optimization techniques which, we feel, fully utilize modern design approaches now available.

Meade Instruments Corporation
1675 Toronto Way, Costa Mesa, Calif. 92626 • **(714) 556-2291**

John C. Diebel, Ph.D.
PRESIDENT

**For a detailed proof of the mathematical statements made here, please write for your copy of Meade Bulletin 800: "A Frank Technical Analysis of Commercially-Available 8″ Schmidt-Cassegrains," free of charge.*

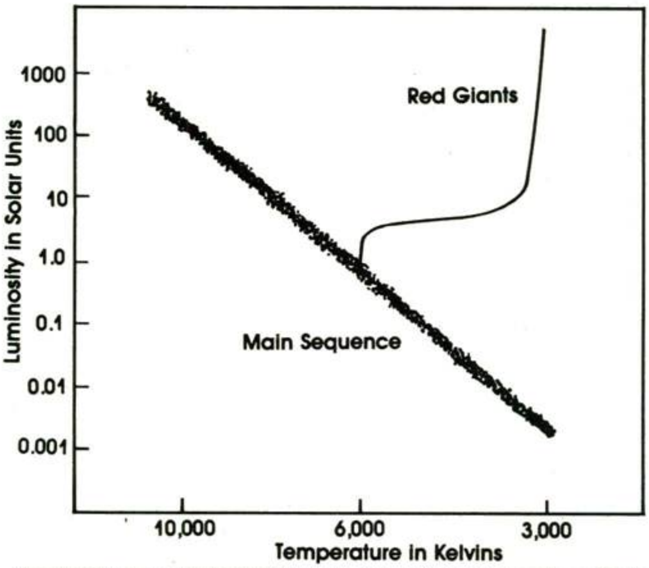
The Vanishing Act of Carbon Giants

by Martin Cohen

When solar-mass stars use up their supply of hydrogen, they expand into luminous red giants and expel matter into space, eventually obscuring themselves in a cloud of dust.

Being a star demands an amazing sense of balance. Throughout their mature lives, stars are constantly pulled inward by gravity as it compresses their inner layers even further, and are held up in their cores by thermal pressure, generated ultimately by nuclear explosions that convert simple elements to those that are more complex. We can observe the success with which stars maintain this equilibrium by examining the Hertzsprung-Russell diagram, a graph of two crucial observational parameters of stars — luminosity (total emitted energy at all wavelengths) plotted against surface temperature. The broad swath cut through the diagram delineates the main sequence — the locus of mature stars.

We also find stars above and to the right of this line which have progressed beyond the main sequence in their evolution. Stars occupying this domain are termed *red giants*. They are red by virtue of their low surface temperatures, and we know their size from the laws of physics. The luminosity of a star is proportional to the area of the radiating suface and also to the fourth power of surface temperature. Consequently, to have a luminosity much greater than the Sun's, stars with a low surface temperature must have a very large radiating surface, and hence, a very large diameter. Some red giant stars are a thousand times larger than our Sun; the entire orbit of the planet Mars would fit inside such an object.



The Hertzsprung-Russell diagram is a plot of two observable quantities — luminosity and surface temperature. Mature stars of various masses lie along its main sequence. When a star such as the Sun exhausts the hydrogen in its core, it becomes more luminous and its surface temperature decreases. It therefore moves to a new position on the H-R diagram.

A red giant is the result of a stellar embarrassment: running out of fuel. Let us again consider our Sun's source of energy — it "burns" the hydrogen in its core into helium, deriving its internal pressure support from the energy generated by nuclear fusion reactions. In a star like the Sun, the "fire" is stable and has already persisted for perhaps five billion years; it will continue for roughly another five billion.

Eventually, however, the central store of fuel begins to run out. As the generation rate of nuclear energy diminishes, radiation pressure — the internal support of the star — decreases. The immense weight of the overlying stellar material begins to dominate. The core contracts rapidly, squeezed by gravity, and causes a liberation of potential energy and an increase in central temperature and pressure. As the net result of running low on fuel, the core shrinks and becomes hotter, burning previously unused hydrogen because of its increased temperature and releasing more energy.

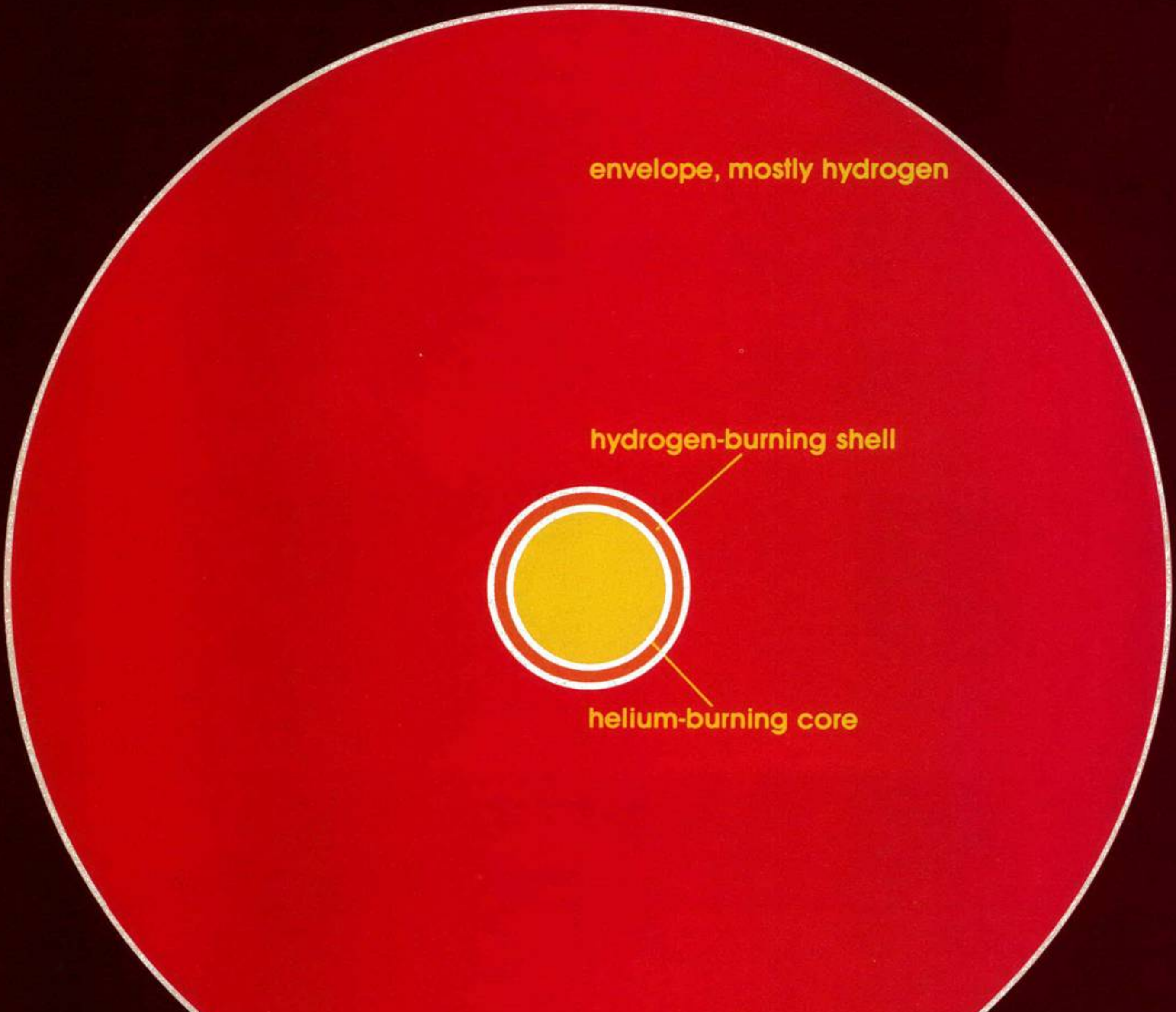
The energy manifests itself by flowing into the outer layers of the star and swelling and distending the star's envelope. As the surface cools, it expands dramatically. The core now has enough pressure to sustain the star against further collapse, and nuclear burning begins to increase again, promoting still greater stellar luminosity and radius.

What would we see if we were to witness a star becoming a red giant from a planet circling it? Initially we wouldn't notice the changes. Our star would maintain an almost constant luminosity while cooling and expanding very slowly. Its surface layers would drop from their original temperature of 6000 K (for a star like the Sun) to perhaps 4000 K, and its radius would double over a billion years.

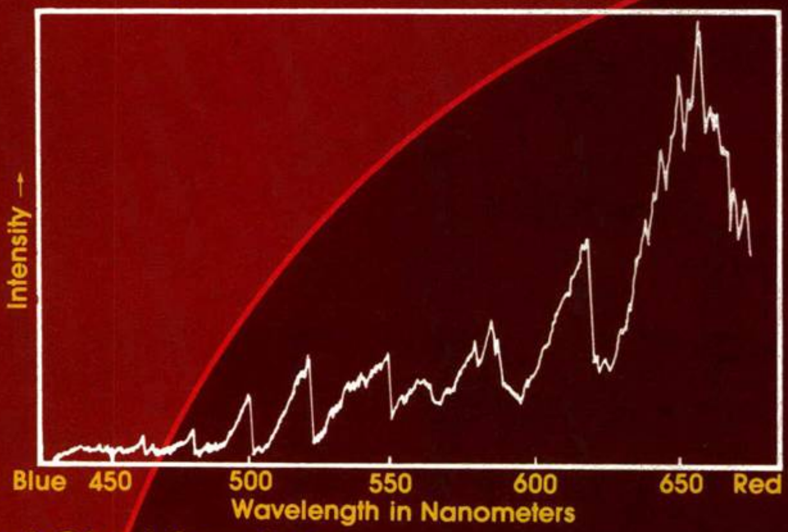
Beyond this point, however, the rate of change increases. As the core burns its remaining hydrogen fuel, the energy output increases dramatically. The star now swells rapidly, so that within 300 million years the diameter of the star would expand to perhaps 100 million miles, a 100-fold increase. Despite the falling surface temperature, the overwhelming increase in surface area would raise the luminosity to a thousand times the solar value. Such a giant would cover almost a tenth of the entire sky as viewed from a planet 1 A.U. away. If we lived on any planet orbiting close to this star, we would be destroyed.

The evolutionary history of a star is pre-determined by its initial mass. From an external viewpoint, as astronomers living on Earth, we see dramatic changes in a star reflected

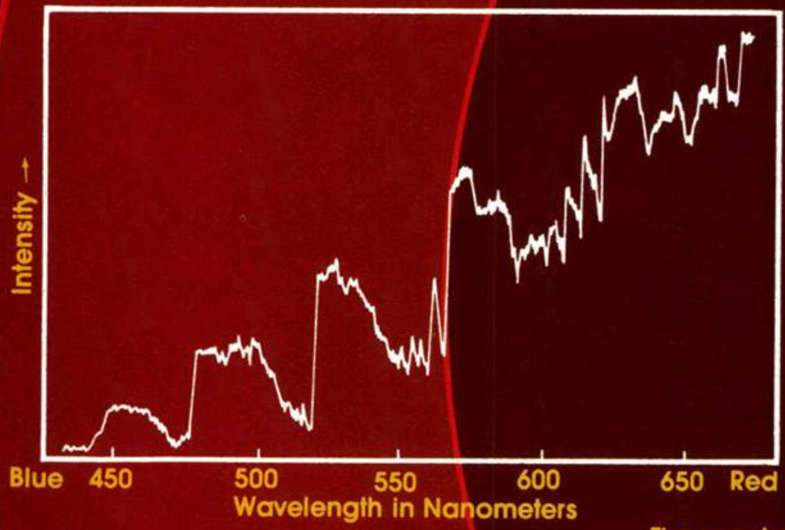
Cross-Section of a Red Giant


envelope, mostly hydrogen
hydrogen-burning shell
helium-burning core

Oxygen-Rich Red Giant Spectrum



Carbon-Rich Red Giant Spectrum



The spectra of normal red giants, both carbon-rich and oxygen-rich, show deep absorption features produced by molecules in their cool atmospheres.

as gyrations in the track it describes on the Hertzsprung-Russell diagram. But if we survey the red giants in our Galaxy, we find that although surface temperature is an important way to characterize the appearance and spectrum of the star, it is not sufficient for a complete description.

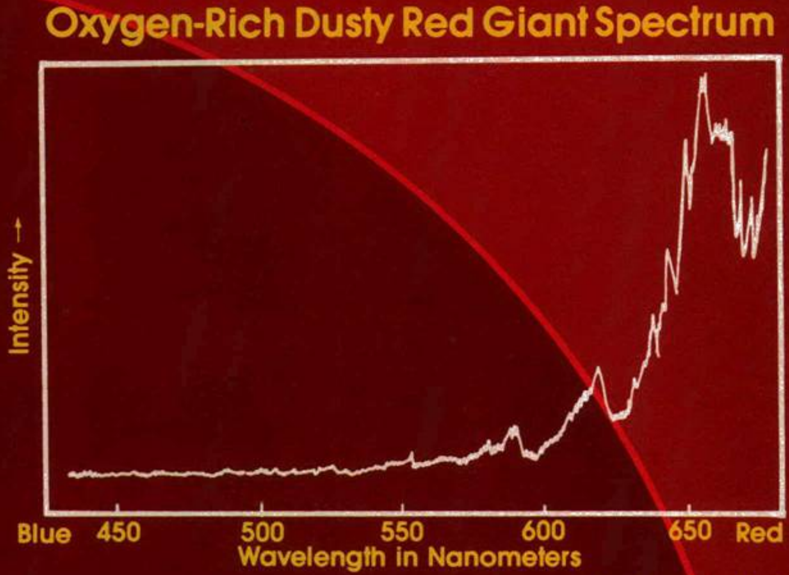
Some stars, for example, reveal absorption features due to oxygen-containing molecules — the oxides of titanium or zirconium. Other stars' spectra show principally carbon-bearing species — such as C_2, C_3, and cyanogen (CN). We don't know exactly what causes these different spectral characteristics, but the ratio of oxygen atoms to carbon atoms in the outer atmosphere of red giants is critical.

Many astronomers suspect that convection converts an oxygen-rich star into a carbon-rich star. Convection stirs up and mixes the outer and inner gaseous layers of a star. In particular, it may dredge up carbon — a product of fusion reactions involving helium — from the interior, and thereby help us observe indirect evidence of helium burning. Whether the average oxygen-rich star will become a carbon star is still a mystery.

Stars over a certain range of mass on the main sequence ultimately become red giants. However, the time required for the transformation depends strongly on their mass. For example, a star 15 times as massive as the Sun becomes a red giant within 12 million years of leaving the main sequence, but our Sun will dawdle along in the metamorphosis for 11 billion years.

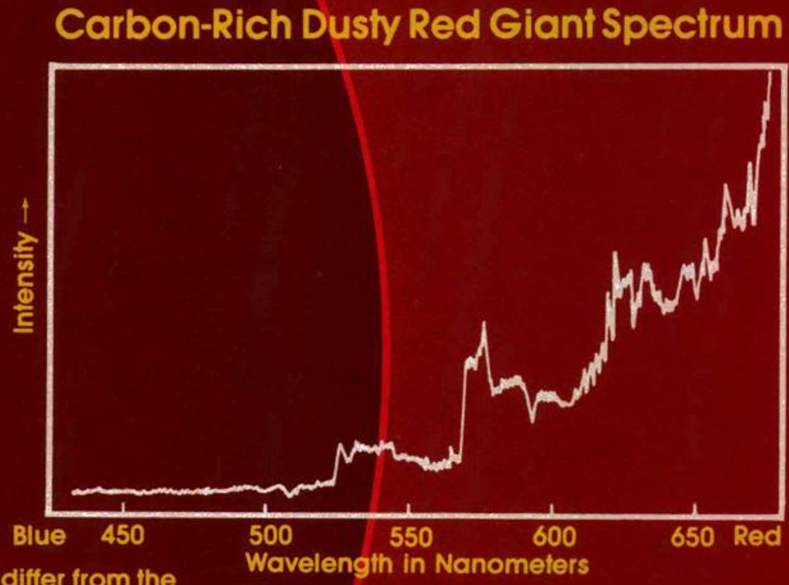
How long a star lingers as a red giant, and what fate awaits it beyond that phase depends on the star's initial mass. Low-mass stars shed their outer atmospheres in the space of a few tens of thousands of years, puffing out gigantic "smoke rings" — planetary nebulae — and eventually leaving the bare core cooling to a tiny white dwarf. Massive stars blow up as supernova explosions, seeding space with their substance and leaving neutron stars in the wake of the catastrophe.

But what becomes of stars in the middle of the range of masses? Until very recently, we didn't know, but studies of the stars in the Magellanic Clouds, our Milky Way Galaxy's satellites, are producing some new information. In our Galaxy, oxygen-rich stars predominate over the carbon-rich stars. But in the Magellanic Clouds, the ratio of carbon stars to oxygen-rich stars found in careful surveys shows a great preponderance of carbon stars — the reverse of the situation in our own Galaxy.



The circumstellar dust shell is far larger than even the enormously expanded envelope of the red giant itself. While the radius of the star may extend 1000 solar radii, the dust shell may swell to 10,000 solar radii.

Typical Dust Shell
Red Giant Star



The spectra of dust-shrouded giants differ from the spectra of normal red giants. They are much more intense in the red part of the spectrum due to light from their dust shells.

One possible explanation for this enigma lies in the fact that the Magellanic Clouds are less enriched in heavy elements than the gas in the Milky Way. This condition, established at the creation of the Clouds, pervades the make-up of every star in them.

Let us suppose that convection brings carbon from the interior of a star to make a carbon star. If potential carbon stars in the Clouds possess fewer heavy elements than their galactic counterparts, then a smaller quantity of carbon dredged up from the interior might be enough to dominate the oxygen in the stellar atmosphere. In other words, it might be easier for a star to be a carbon star in the chemical environment of the Clouds where both oxygen and carbon are relatively rare.

What kind of evidence could corroborate or refute this idea? Suppose we examine the sky at different wavelengths in search of red giants. What happens to the ratio of carbon to oxygen stars as a function of survey wavelength? In visible light — about 0.5 micron wavelength — oxygen stars dominate carbon stars by a factor of around 50. In the near-infrared, at 2 microns, or four times typical visual wavelengths, the factor falls from 50 to only several times. As we continue into the infrared, the ratio continues to fall until, at 20 microns wavelength, we find roughly equal numbers of O and C stars.

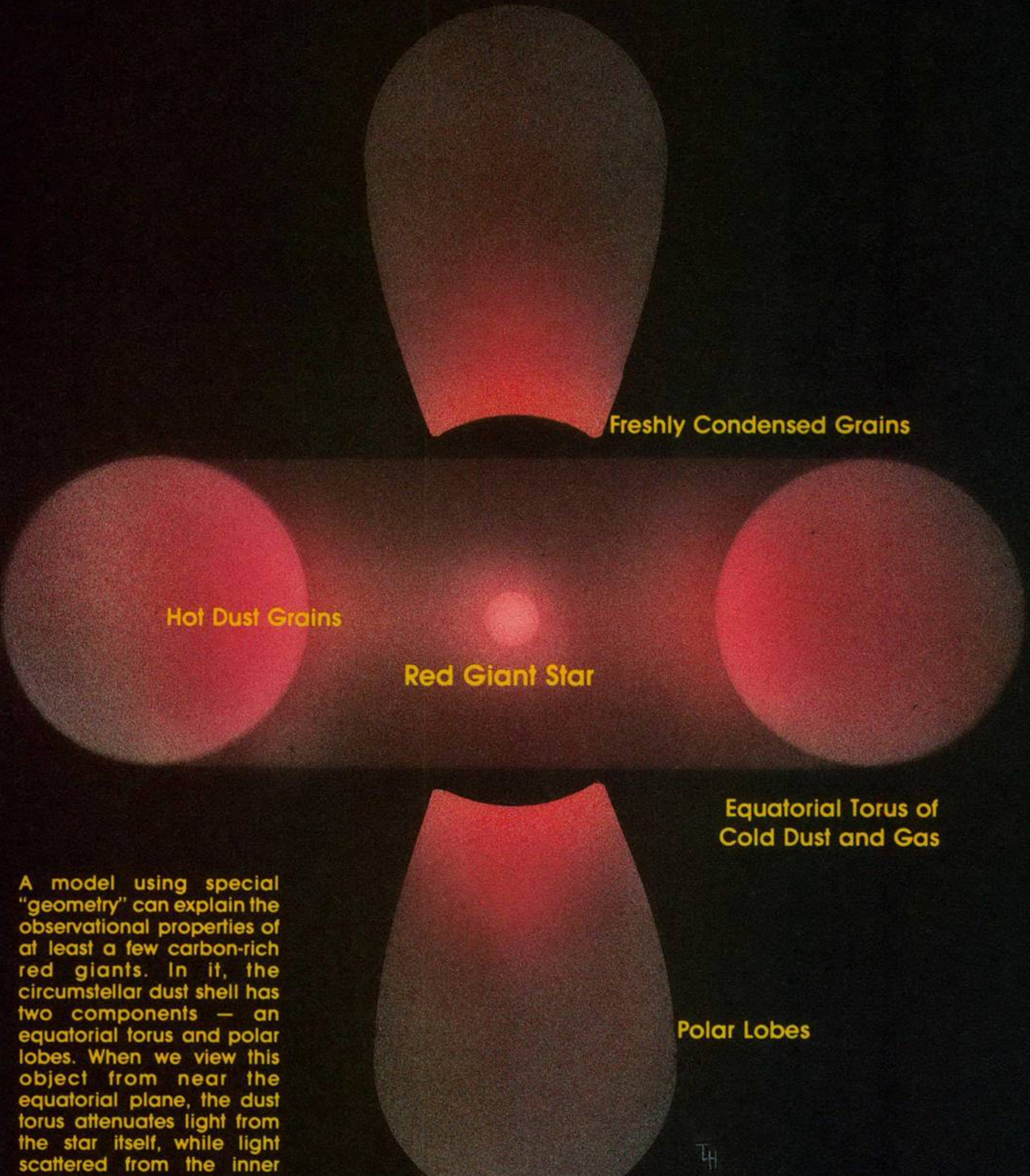
But why are red giants so bright in the infrared? And why are carbon-rich C stars preferentially uncovered by these surveys?

We know the color and surface temperature of a star are intimately related. Sirius, at 10,000 K, appears bluish, while Betelgeuse, at about 3000 K, is orange. As stellar temperatures are reduced, the peak of their radiated energy shifts to longer wavelengths. The near-infrared sky is dominated by cool red giants.

Giants are characterized by phases in which they shed the outer gaseous layers of their atmospheres. If these gases are sufficiently dense, small solid "grains" of dust can condense as the gases move outward from the star and cool. These tiny grains add their mass to previously accumulated debris around the star. They also block light.

Dust shells that belong to and are heated by individual stars are termed *circumstellar shells.* Red giants undergo short-lived phases of high mass ejection, so it is likely that they accumulate large reservoirs of circumstellar dust. The dust grains absorb starlight and are heated to several hundred degrees Kelvin. Then they re-radiate energy into

Carbon-Rich Red Giant Star


Freshly Condensed Grains
Hot Dust Grains
Red Giant Star
Equatorial Torus of Cold Dust and Gas
Polar Lobes
TH

A model using special "geometry" can explain the observational properties of at least a few carbon-rich red giants. In it, the circumstellar dust shell has two components — an equatorial torus and polar lobes. When we view this object from near the equatorial plane, the dust torus attenuates light from the star itself, while light scattered from the inner edges of the lobes is strongly polarized.

space in the long-wave infrared region of the spectrum. Thus red giants, or rather their circumstellar shells, shine brightly at wavelengths of 10 or 20 microns.

Circumstellar shells are low in temperature. And, in order to be as luminous as they are, they must have enormous sizes — much larger than the red giants themselves. Typical circumstellar shells have radii of over ten billion miles, or one hundred astronomical units — big enough to encompass all the planets of our solar system.

These shells convert visible energy into infrared radiation. A star that is highly luminous in the infrared must suffer a substantial conversion of starlight to infrared in its dust shell. Consequently, far-infrared surveys reveal optically faint giants with very thick and extensive dust shells.

The kind of dust produced by stellar mass outflow depends crucially on the oxygen to carbon ratio of the star's atmosphere. Gas flowing from an oxygen star condenses into silicate grains such as magnesium silicate — talcum powder. Carbon stars convert gaseous ejecta primarily into graphite and silicon carbide — carborundum. Infrared surveys seem to locate carbon stars preferentially. This is probably because carbon-rich dust grains condense more readily from ejected stellar gases, or are better at converting visible starlight into infrared.

Properties of Dusty Red Giants

Oxygen-Rich Stars

Name[1]	Visual Mag.	Distance (l.y.)	Shell abs.[2]	Stellar radius[3]	Shell radius[3]
1686	18	5600	6	—	—
2171	13	2000	2	—	—
2241	18	1900	8	—	—
2425	16	5600	3	—	—
2885	14	3100	3	—	—

Carbon-Rich Stars

Name[1]	Visual Mag.	Distance (l.y.)	Shell abs.[2]	Stellar radius[3]	Shell radius[3]
799	16	14000	8	0.4	5.6
1381	>21	700	13	0.7	17.5
1403	16	600	9	0.2	3.1
2232	13	2600	5	0.3	3.8
3116	20	3300	13	0.4	8.8

[1] Catalog number from an infrared sky survey made by the US Air Force Geophysics Laboratories.

[2] Given in magnitudes of starlight absorbed.

[3] Given in billions of miles. These numbers have not yet been individually estimated for oxygen-rich stars.

We can obtain visible-light spectra from the central stars embedded in many of these dust-obscured giants. These spectra reveal that the stars have very cool atmospheres — typically 2000 K to 2500 K — and dust shells that transmit only one-one hundredth to one-millionth of the light from the star — 5 to 15 magnitudes of obscuration. One carbon star that we now see at magnitude 15 would rival Vega in brightness if it had no circumstellar shell.

The continuing mass loss from these stars contributes more obscuring dust to their shells. These faint stars must, therefore, represent the last visible evolutionary phase of these red giants. Beyond this, they will simply disappear from the view at optical wavelengths. This is the tantalizing aspect of their lives that makes their study and understanding so crucial.

During the past two years, I have been monitoring a sample of thirty giants discovered by infrared surveys. Most are C stars and all are highly obscured visually. I have hoped to learn something about their mass outflows by answering these questions: Is material lost continuously, or sporadically in "puffs"? How much mass is lost? How fast are the gases ejected? Do the winds blowing from these stars come from the whole stellar surface, or just some areas of it? What can we learn about the shape of circumstellar shells?

The behavior of one star has been highly revealing. Normally its spectrum shows a well-defined, cool carbon star atmosphere. However, on several occasions in the last two years, the star has displayed unusual spectra. Absorption features have been oddly absent in the blue and yellow parts of the spectrum, and we've found strong atomic emission lines on top of the resulting continuous spectrum. These lines and relative strengths have been consistent with a relatively high-speed shock where outflowing gas has collided with other material at speeds close to 100 km/sec, and heated it to high temperatures. As the gas cools, it emits these characteristic lines.

Certainly this star undergoes short periods of intense activity when it sheds its gas at a rapid rate. But some hydrogen line emissions are always present, indicating that a low level of mass loss occurs continuously. The smooth spectrum results from incandescent dust grains — at temperatures close to 2000 degrees — swamping the normal stellar spectrum. These grains must form either within the high-speed ejecta or from impact on pre-existing circumstellar material.

Optical polarization provided another clue to the geometry of the dust cloud. Strong red and blue polarization from different directions indicates that we view this carbon giant from its equatorial plane through a dark, dusty, doughnut wrapped around its equatorial regions. In blue light we see radiation from the hot dust grains scattered from and polarized by dust particles in the polar directions. In the red, we see starlight heavily attenuated by direct transmission through the dust disk. The atomic emission line phase seems to herald the condensation of fresh dust grains in a ring at the inner edge of the doughnut.

Continued monitoring of these objects suggests that this sequence of events is periodic — at least for one star. This star is now displaying its bright atomic lines for the second time in two years. The "doughnut with polar lobes" geometry is not unusual in astronomy — it occurs at three other times: in very early stellar life while a star is on its way to the main sequence, at the death of carbon giants, and at least in one oxygen giant. In the cool star, rotational shedding of equatorial material is probably responsible.

I am now investigating a couple of the other carbon stars that have also shown atomic emission lines — though less prominently than the star described. Such studies will, I hope, point to the next phase of evolution of these giants and provide a clue to the masses of stars that undergo this type of sporadic mass ejection — still an unclear issue.

In the meantime we can use other approaches to learn about these stars. The infrared-bright giants have extensive envelopes of molecular gases that we can study in the radio microwave part of the spectrum at wavelengths of a few millimeters. And arrays of radio dishes, acting as interferometers, may one day help us resolve the equatorial torus and polar lobes structure around some of these stars. What makes this phase of evolution especially fascinating is the intriguing prospect that we may be witnessing the last gasps of the red giant phase and the start of the next phase of evolution about which we can now only speculate.

Martin Cohen's most recent ASTRONOMY article was "Do Supernovae Trigger Star Formation" in the April 1982 issue. He is an astronomer at NASA's Ames Research Center and the University of California, Berkeley.

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ANNOUNCEMENT — The Active Amateur Astronomers of Maryland (AAAM) will be holding meetings on Monday March 22, Thursday April 19, and Wednesday, June 23. In May there will be a star party in Monkton. All meetings except the star party will be held at the Hamilton Branch of the Enoch Pratt Library on Harford Road from 7 to 9 p.m. Bring your scopes as we go observing after the meeting if skies are clear. The AAAM is building a forming gas chamber, so bring your film, especially 2415 type. For information contact Bob Calhoon, (301) 444-5668, or Doug Cook, (301) 254-6261.

ANNOUNCEMENT — Any astronomy club that has access to a Sinclair microcomputer and wants programs for it for their club, contact Robert Calhoon, 2616 Roselawn Avenue, Baltimore, MD 21214.

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ANNOUNCEMENT — The Great Lakes Regional Convention of the Astronomical League will be held on July 16-18, 1982 at Cranbrook Institute of Science, Bloomfield Hills, Michigan. Hosted by the Warren Astronomical Society. Contact Lou Faix, 6088 Robin Hill Road, Washington, MI 48094.

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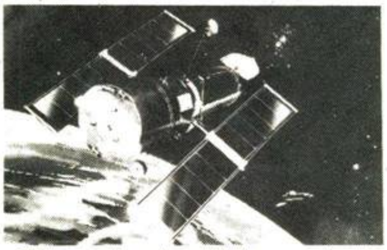

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ANNOUNCEMENT — The Astronomical Society of Kansas City meets on the Fourth Saturday of each month. Meetings start at 7:30 p.m. in room 103 of Haag Hall Annex at the UMKC campus. The annex is located between Rockhill Rd. and Holmes on 52nd St. For information, phone Gary Pittmann, (816) 229-2677.

ANNOUNCEMENT — ATTENTION, professional astronomers and astronomy educators. The Amateur Space Telescope Project desires your input. Write to the Independent Space Research Group, P.O. Box 1246, Troy, NY 12180.

ANNOUNCEMENT — The Southwest Washington Astronomical Society has expanded into the Olympia, Longview and Aberdeen areas. For meeting dates, contact Carl Newton, 2421 Leisure Lane, Centralia, WA 98531. Phone (206) 736-6144.

ANNOUNCEMENT — The East Texas State University Star Trek Club will be hosting a Star Trek Convention on the E.T.S.U. campus on April 30 and May 1. Please write for more information to: Star Trek Club, P.O. Box 3656 ET Station, Commerce, TX 75428.

ANNOUNCEMENT — M-31 Astronomical Society of Erie, Erie, Pennsylvania, meets once each month. Expansion desired to implement new activities, programs, star parties. Professionals, amateurs, and arm-chair enthusiasts welcome. Contact Bob Reisenweber, 3621 Ridge Parkway, Erie, PA 16510. Phone (814) 899-2560.

ANNOUNCEMENT — The ASTRONOMY CLUB OF AKRON will host an OHIO TURNPIKE ASTRONOMER'S CONVENTION, Saturday June 26, 10 a.m. to 4 p.m. in Akron, Ohio. Lectures — variable stars, radio astronomy, telescope making. Admission $1.50. For information contact Philip L. Hegenderfer, 5070 Manchester Rd., Akron, OH 44319. Phone (216) 644-0230.

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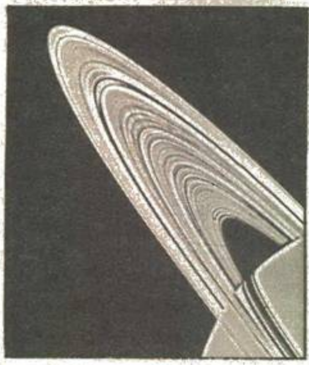

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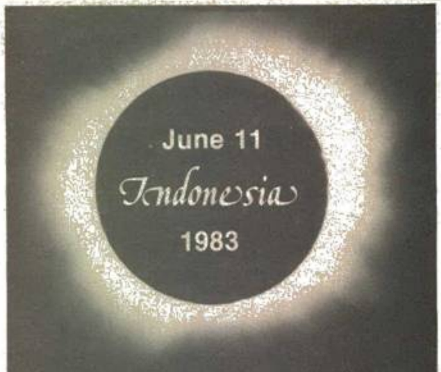

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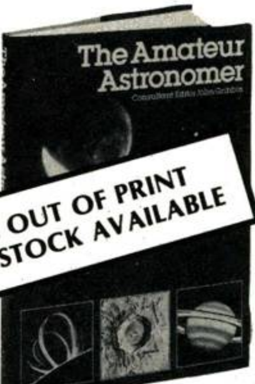

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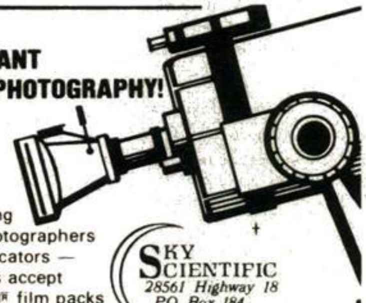

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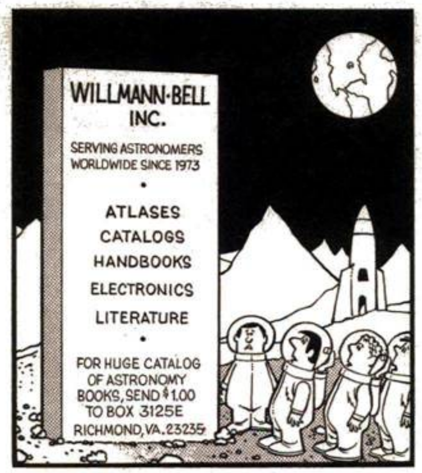

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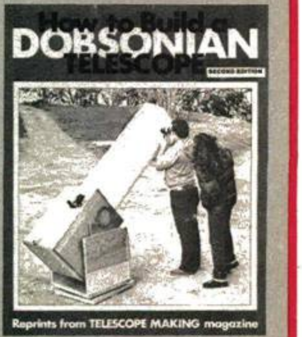
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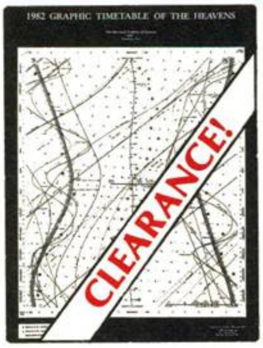

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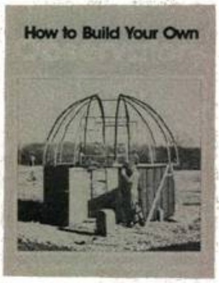
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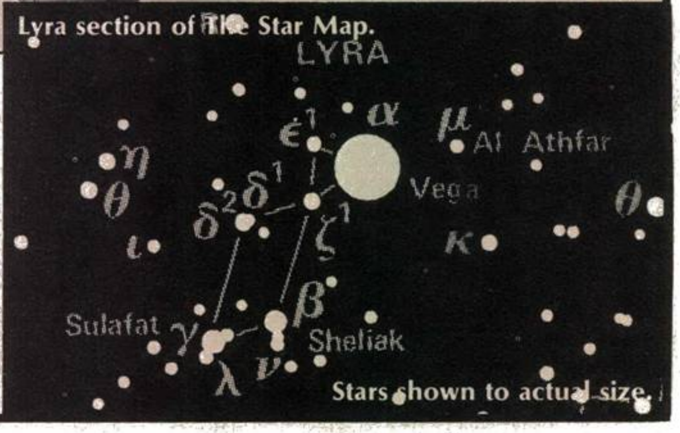

Lyra section of The Star Map.

Stars shown to actual size.

the backyard astronomer

corona borealis / serpens caput

Mercury

After passing through inferior conjunction on June 1, Mercury will move quickly into the morning sky and make a brief and not very favorable appearance. It will be visible during roughly the latter half of June and the first half of July. Greatest western elongation comes on June 26 with greatest elevation occurring about a week later. At maximum, Mercury will be only 6° high in the east-northeastern sky, 45 minutes before sunrise.

On the 20th, the Moon will pass just to the north of Mercury; observers in the arctic (both eastern and western hemispheres) and the northern parts of Asia and Europe will see an occultation. A few days later, on the morning of the 23rd, Mercury will pass close (1° 41′) to the north of Aldebaran, α Tauri. The planet will then be a crescent — 8.7″ of arc across and 28% lit. Mercury's magnitude will be +1.0, Aldebaran's +0.9.

Venus

Venus is the bright and prominent object low in the eastern sky during the hours before sunrise. Day by day, it is moving steadily northward along the horizon and gaining a little in altitude and visibility; it remains at around -3.4 magnitude. A telescope will reveal a disk about 14″ of arc in diameter and 75% "full."

Earth

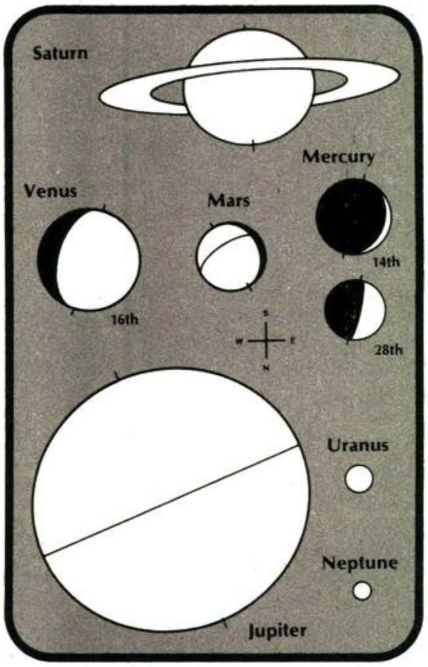
The Sun reaches its solstice at 17:23 UT on June 21. At this time it will lie 1.017 AU distant; two weeks later, on July 4, Earth will be at its farthest distance from the Sun — aphelion.

The afternoon Sun slants across the rugged walls of the 100-km crater Theophilus (center) on the shore of Mare Nectaris. L.H. Price used a homebuilt 6-inch f/7 Newtonian and eyepiece projection to take this photo on Tri-X with a ½-second exposure at f/80. He earned the "Best Astro-Photo Award" for June.

Moon

Early next month — on the night of July 5/6 — the Moon will pass almost centrally through the Earth's shadow, producing what promises to be a spectacular lunar eclipse. Here's some basic information to let you plan your observations — and maybe an eclipse party, too!

The first touch of the Earth's penumbra comes at 4:22 on July 6; first umbral contact is at 5:33; totality runs from 6:38 to 8:24 with mid-eclipse at 7:31; last umbral contact is at 9:29 and last penumbral contact at 10:40. (All times are in UT; to convert to your local daylight time, see the box in "Planetary Data" on page 80.)



For observers in the east, the Moon will be setting during the entire eclipse and, by the close of the penumbral phase, the Sun will have risen. The farther west you go across the continent, the better the circumstances: from the west coast, the Moon will be nicely placed in the southeastern and southern sky.

Mars

The Red Planet's eastward motion will bring it almost far enough to overtake Saturn by the end of June. During this time, it is a small red-orange dot that loses 20% of its apparent size: from 10.7″ of arc in diameter on June 1, it shrinks to 8.7″ on the 30th. It also dims by half a magnitude.

The disk of Mars displays a distinctly non-circular shape. The reason for this small phase-effect is that the geometry of the Sun-Mars-Earth triangle places us where we peek slightly around the morning limb of the planet. The gibbous, out-of-round shape will become a bit more pronounced by the end of July. It returns to its circular shape by the time the Sun overtakes Mars in the evening sky early next year.

Asteroids

1 Ceres (magnitude 7.2) lies in western Libra. Its positions:

10th: 14h 51m 49s, -9° 37.2′
20th: 14h 47m 34s, -10° 09.4′

Ceres sets around 4 a.m. local daylight time on the 15th.

2 Pallas (8.8) is in central Coma Berenices. Its positions:

10th: 12h 54m 32s, +22° 15.4′
20th: 12h 59m 35s, +21° 29.4′

Pallas sets about 3:30 a.m. local daylight time in the middle of June.

3 Juno (10.0) crosses from Scutum into Serpens Cauda around the 11th of June and into Ophiuchus at the end of the month. Its positions:

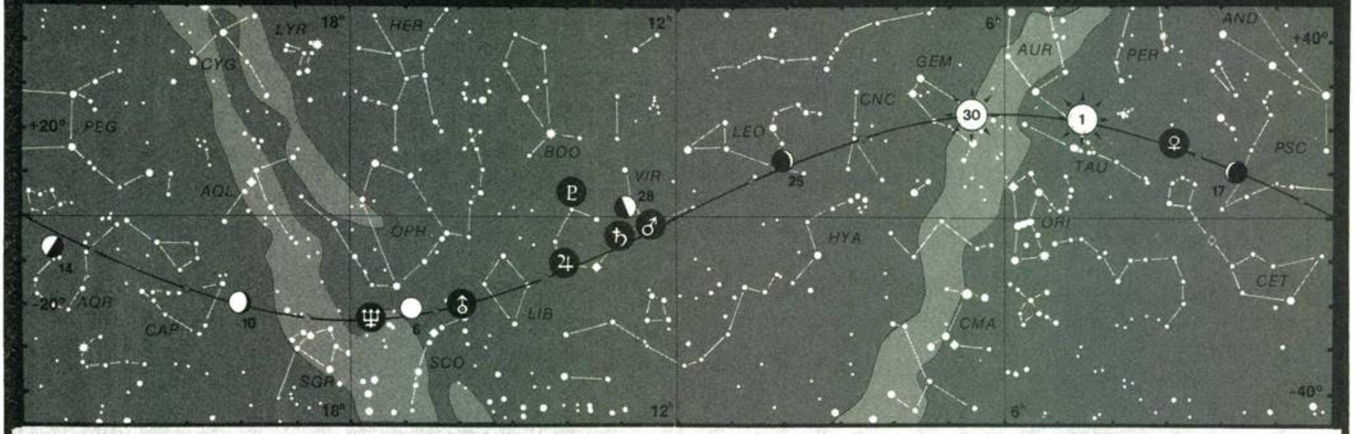
10th: 18h 19m 23s, -4° 55.0′
20th: 18h 11m 04s, -4° 47.9′

Juno is at opposition on June 24.

4 Vesta (6.8) lies in eastern Capricornus, just to the north of Delta (δ) Capricorni. Its positions:

10th: 21h 45m 16s, -16° 17.5′
20th: 21h 49m 43s, -16° 41.2′

planetary data june 1982


LYR
18h
HER
12h
6h
AND
+40°
CYG
GEM
AUR
PER
+20°
PEG
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30
1
BOO
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25
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14
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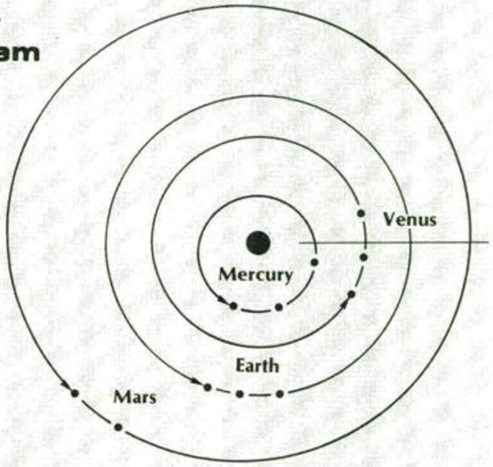
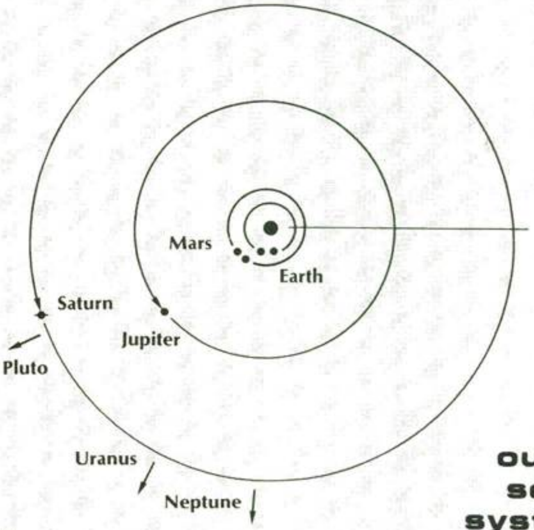
18h
12h
6h
-40°

inner solar system


Venus
Mercury
Earth
Mars


Mars
Earth
Saturn
Jupiter
Pluto
Uranus
Neptune

outer solar system

				Angular	%	Distance (AU) from:		Longitude:			
		Date	Mag.	Size	Illum.	Earth	Sun	Heliocentric	Ecliptic	R.A. (1982.5)	Dec
Sun		1	-26.7	31.6′	—	1.01	—	—	70°11.9′	4h 34.2m	+21°58.7′
		15	-26.7	31.5′	—	1.02	—	—	83°35.3′	5h 32.0m	+23°17.1′
		30	-26.7	31.5′	—	1.02	—	—	97°54.3′	6h 34.4m	+23°12.3′
Mercury	☿	1	+3.2	12.1″	0%	0.55	0.47	248°44.0′	70°59.4′	4h 40.8m	+20°04.7′
		15	+1.7	10.5″	13%	0.64	0.45	288°01.6′	66°12.6′	4h 22.3m	+17°12.3′
		30	+0.4	7.4″	45%	0.90	0.38	340°01.5′	75°44.4′	5h 01.2m	+20°00.4′
Venus	♀	10	-3.5	14.0″	77%	1.20	0.73	344°26.0′	41°19.7′	2h 39.9m	+13°24.9′
		30	-3.4	12.6″	83%	1.33	0.73	16°14.9′	64°52.5′	4h 14.8m	+19°36.5′
Mars	♂	15	+0.2	9.6″	89%	0.97	1.56	226°06.8′	186°22.7′	12h 25.0m	2°31.1′
Jupiter	♃	15	-1.9	41.4″	99%	4.76	5.43	219°16.1′	210°16.1′	13h 56.1m	-10°29.3′
Saturn	♄	15	+0.9	18.0″	100%	9.26	9.69	201°06.0′	195°04.7′	13h 01.1m	-3°42.4′
Uranus	⛢	15	+5.8	3.8″	100%	17.94	18.88	242°53.4′	241°21.9′	15h 58.7m	-20°21.5′
Neptune	♆	15	+7.7	2.5″	100%	29.26	30.27	265°39.5′	265°16.7′	17h 41.6m	-22°03.3′
Pluto	♇	15	+13.8	—	100%	29.45	29.95	205°58.6′	203°52.2′	13h 55.1m	+6°26.1′

moon data

Full Moon	June 6 at 15:59
Last Quarter	June 14 at 18:06
New Moon	June 21 at 11:52
First Quarter	June 28 at 05:56
Full Moon	July 6 at 07:32
Last Quarter	July 14 at 03:47
Apogee: June 7 at 23h	406,148 km
Perigee: June 21 at 12h	357,572 km

universal time

Astronomers the world over use an unambiguous system of time reckoning — Universal Time (UT) — based on a 24 hour clock. Times given in The Backyard Astronomer are UT unless noted otherwise. To convert UT into your local daylight time, subtract the following number of hours for each time zone: EDT, 4; CDT, 5; MDT, 6; PDT, 7; Alaska, 9. For example, if an event is to happen at 03:00 hours UT on June 7, then EDT for the event is 11 p.m., June 6. Likewise, 03:00 UT on September 2 becomes, in PDT, 8 p.m., September 1.

M-39 is a sparse and loosely-gathered open cluster that lies in the Milky Way's run through Cygnus. The triangle-shaped grouping shows about 30 members in a telescope and lies 900 light-years away. Jack Newton took its picture in 10 minutes with a 16-inch f/5 telescope using ASA 400 film and a cold camera.

Vesta rises around 12:30 a.m. local daylight time in the middle of the month.

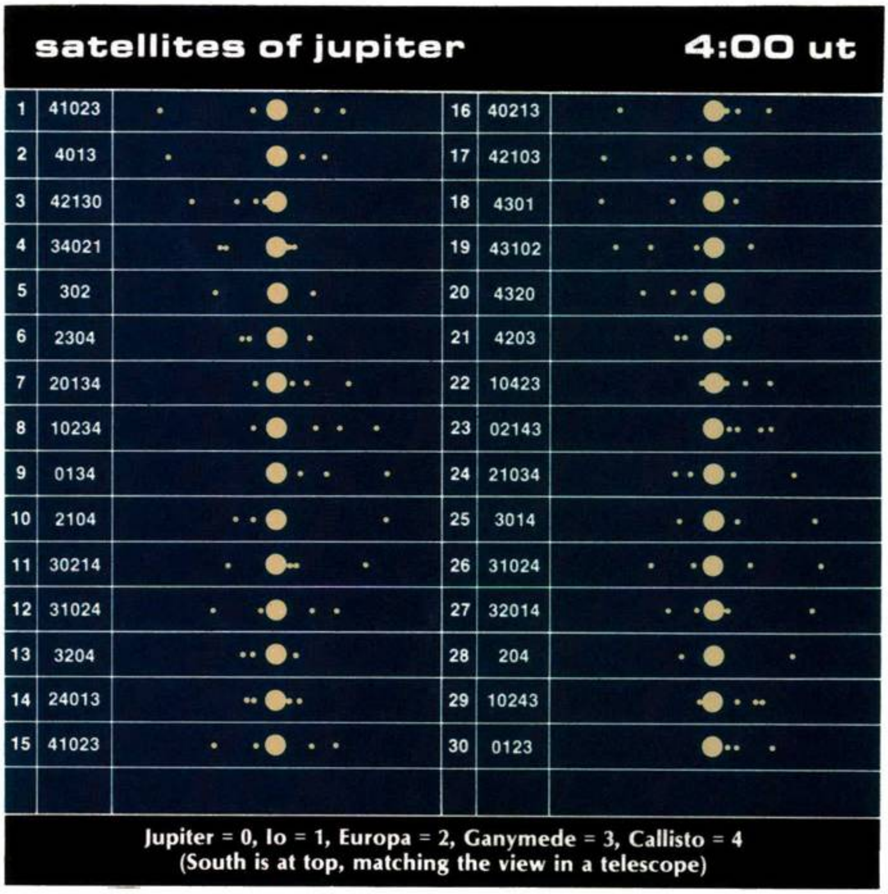
All asteroid positions are in 1950 coordinates.

Jupiter and Saturn

Not every backyard observer has — or even wants — a camera on his telescope. If you're among the multitude in the "eyeball brigade," you might want to try your hand at sketching the atmospheric features of the gas giants. It's less difficult than you might think.

Let's begin with Jupiter. Apart from your telescope, the equipment is downright simple: a few pencils, an eraser, and an oval blank to help you outline the jovian disk. A store that sells art or office supplies will probably have everything you need. Get three drawing pencils, one each in 2H, HB, and 2B grades. Draw the Jupiter blank with a 70° ellipse template; use one that has ellipses in the 1" range.

satellites of jupiter 4:00 ut



1	41023	16	40213
2	4013	17	42103
3	42130	18	4301
4	34021	19	43102
5	302	20	4320
6	2304	21	4203
7	20134	22	10423
8	10234	23	02143
9	0134	24	21034
10	2104	25	3014
11	30214	26	31024
12	31024	27	32014
13	3204	28	204
14	24013	29	10243
15	41023	30	0123

Jupiter = 0, Io = 1, Europa = 2, Ganymede = 3, Callisto = 4
(South is at top, matching the view in a telescope)

Above: Last December, before Venus sped between the Earth and Sun, David Fabrizio photographed it through an 8-inch f/6 telescope with ¼-second exposure on ASA 160 film. Right: John Gleason used a 5-inch f/1.65 Schmidt camera and a 20-minute exposure on 200 ASA film to capture M-8 and M-20.

Pick a night when the seeing is good, set up your scope, put in a medium to high-power eyepiece, and focus on Jupiter. Take your template and draw a Jupiter oval about an inch across on a sheet of plain white paper. The lower the power you use, the smaller the oval should be. Working carefully, but not laboriously, sketch in the features you see using the HB pencil. Use the other grades for details, but try not to make the features in the drawing too dark.

Sketching Saturn is a lot more difficult; you'll see fewer details, and the ever-changing aspect of the rings makes any template out of date in a few months. A 60° ellipse approximates the planet's shape pretty well, but the rings call for templates that range from 5° to 25°. Currently, the rings are tipped about 10° to our line of sight.

Don't work too long on any one disk drawing. Both Jupiter and Saturn rotate rapidly and half an hour is plenty long enough for one drawing. If you take much longer than that, you'll find the limb features have changed too much. When you finish a sketch, note on it the date and time, the instrument you used, eyepiece power(s), and a rating for the seeing conditions. Be sure to save all your sketches — yes, even those wretched first ones. You'll be astounded at how fast your skill has developed.

Uranus

A month past opposition, Uranus is just within the limits of naked-eye visibility. Any optical aid will show the planet clearly, but you'll need a telescope if you want to make out the 3.8″ of arc disk.

Find Uranus by locating Beta (β) Scorpii, a bright third magnitude double star to the northwest of Antares. Then sweep south and a little east of Beta to find the pair of stars that comprise Omega (ω). Uranus lies to the west of Omega by a little more than the distance that Omega lies south of Beta.

Neptune

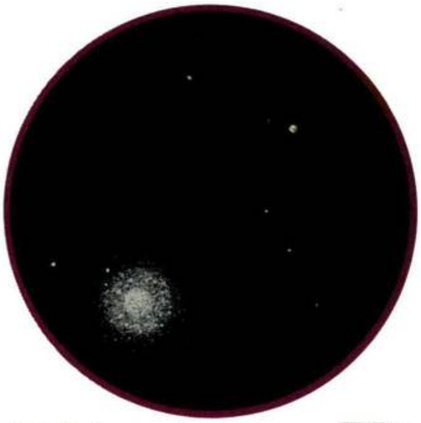
At opposition on June 17, Neptune is more difficult to find than Uranus: it's fainter and has a smaller disk. In addition, it lies in a richer star field.

One way to find it is to draw a line between Eta (η) Ophiuchi and Lambda (λ) Sagittarii, the star at the top of the Teapot's lid. Halfway between Eta and Lambda, and a little to the south, lies 4.9 magnitude 58 Ophiuchi. Neptune lies about half a degree south of this star.

close-up on corona borealis/ serpens caput

With the approach of June, night-time weather becomes progressively milder for northern hemisphere observers, and promotes a resurgence of backyard observing. If you find yourself dusting off the scope that's been in storage since last November, and you're ready to gear up for a few months of observing, take a few minutes to devise a plan of attack. The summer skies are laden with deep-sky objects and rich Milky Way fields — more than enough to keep you out in the dark until the wee hours. Just try not to get too engrossed, or you might

M-5 and 5 Serpentis



James Mullaney **50x**

sleep right through your 7 a.m. alarm.

A good place to start your night of observing is **Corona Borealis** — nearly straight overhead at 10 p.m. You can't miss this constellation. It actually looks like its namesake, a crown, without a stretch of the imagination — and not many sky patterns do! Corona Borealis is full of variable stars and even contains a distant galactic cluster much like the one in Coma Berenices. To start, first notice the rim of the semicircle formed by seven stars — that's the constellation. The brightest star, **Alpha** (α), known as **Alphecca**, or **Gemma**, is a 2nd magnitude sun about 75 light-years away. It marks the bottom of the crown.

Next is the double, **Gamma** (γ) **Coronae Borealis**, a pair of stars shining at magnitude 4.2 and 5.6. They are easy to separate in small scopes. After that comes **Eta** (η), which is a little harder to split; you'll need at least a 6-inch at high power to detect the two stars. Both are very similar to our Sun and are 50 light-years away. Their magnitudes are so close, at 5.7 and 6.0, that this pair will be a test of your optics.

Moving on around the edge of the circle you'll find **Sigma** (σ), a good binary for small telescopes. T.W. Webb said that there was a "great divergence as to the colors," but later observers state the colors are nearly the same for both — just plain white. Use a medium-power eyepiece to resolve this pair.

Located in the center of the bowl-shape is **R Coronae Borealis**, the strange irregular variable that E. Pigott discovered in 1795. Robert Burnham, Jr. describes it as "a typical example of a rare class of variables that remain at maximum throughout most of their cycle." Most of the time this star shines at about 6th magnitude. However, it will suddenly fade, and come to rest anywhere between 7th and 15th magnitude, but usually around 12.5. Strange indeed! For several months it will stay at this brightness and then will suddenly brighten again. While it is at minimum, its light is very erratic and follows no predictable pattern. Astronomers can't even predict when it will drop in brightness.

Don't miss this intriguing object; if it's not readily visible as a 6th magnitude star, then get out your scope and try to find it. Astrophysicists think that a large cloud of carbon, literally a "soot cloud," periodically swells up and blocks the light. Nearly 67% of the star's atmosphere is composed of carbon. As this cloud clears, or is reabsorbed by the star, the light returns to normal. Spectrum measurements show very little hydrogen in this star, indicating that it is possibly in the last stages of its life cycle.

Even T.W. Webb knew something was amiss with R Coronae. He described it as "one of the most remarkable variables in the heavens, remaining sometimes for a year without alteration in light, sometimes falling rapidly. The spectrum is peculiar, having bright lines, but probably not those of hydrogen."

The last unusual star in this constellation is **T Coronae Borealis**, the famous "Blaze Star" and the best example of a recurrent nova. Although now at approximately 10th magnitude, it has risen twice in the last century to as bright as 2nd magnitude, only to fade away again. There are only "six other stars known to have undergone more than one nova outburst, but T Coronae is by far the brightest," said Burnham. Other examples of recurrent novae are: RS Ophiuchi, U Scorpii, VY Aquarii, T Pyxidis, WZ Sagittae, and V1017 Sagittarii.

Although not in the range of most backyard instruments, the **Corona Borealis Galaxy Cluster** deserves mention. Located in the southwest corner of the constellation, it contains more than 400 galaxies all lying at a distance of 1.3 billion light-years. Most of the members are ellipticals, and the brightest are 16th magnitude. This cluster is very similar to the Virgo Cluster, but its galaxies are more distant, and therefore fainter and in a smaller field. If you have a large scope in the 17 to 20-inch range, try to locate this remote cluster of galaxies.

While you're in this section of sky, drop your scope straight down between Ophiuchus and Corona Borealis. Here you'll find the constellation **Serpens** divided into two parts symbolizing the Head and Tail of a serpent. **Serpens Caput**, the part we're interested in, lies on the east side of Ophiuchus, while the tail (Cauda) lies on the west. This region of the sky is close to the Milky Way and holds some fine sights for the telescopic observer.

The head of the serpent is formed by most of the bright stars in the constellation. **Alpha** (α), called **Unukalhai**, from the Arabic "neck of the snake," is a double with a 2.6 magnitude primary and a much fainter companion that shines at magnitude 12. R.H. Allen called the colors pale yellow and blue.

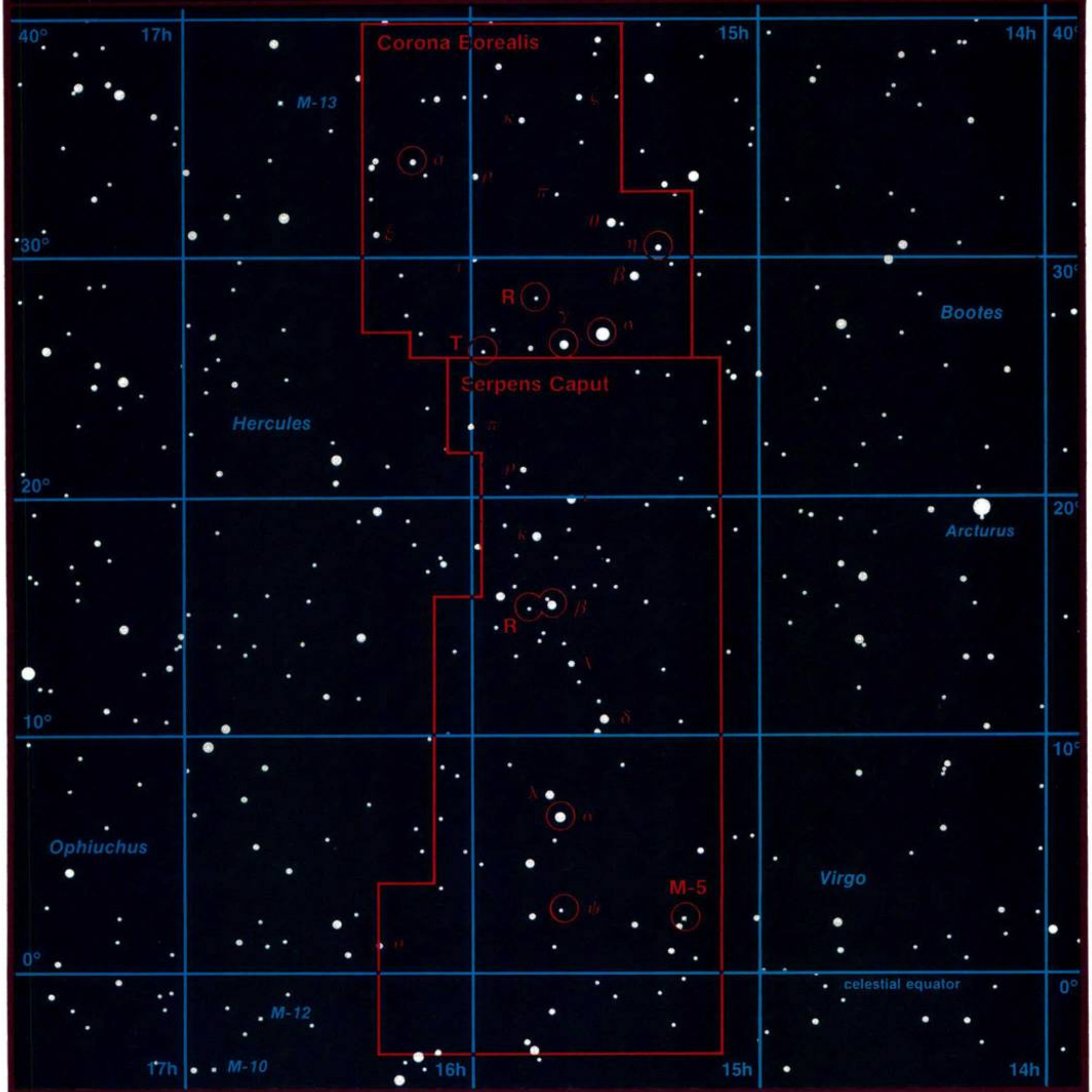
Beta (β) **Serpentis**, magnitude 3.7, marks the head of the serpent, and K. McKready said "it should first be examined with a low-power eyepiece. The field near it, especially a little way to the northeast, is a fine spectacle even in opera glasses." Beta itself has a 9th magnitude companion and both stars are described as bluish. Just slightly more than one degree to the east-southeast lies the long period red variable **R Serpentis**, that Burnham says is "one of the most suitable variables of the class for observation with small instruments."

Return now to Alpha and use it as a guide for our next object, the multiple star **Psi** (ψ) **Serpentis**. Four degrees south of Alpha, Psi shines at 5.9 magnitude. It has a 12th magnitude companion about 4 seconds away to the northeast. Burnham mentions two other members, one of 9th magnitude almost 4' of arc to the southwest, and the other of 10.5 magnitude 3' away toward the north-northwest.

The last object we'll look at tonight is one of the true showpieces of the heavens — the globular cluster **M-5**. This compact group of stars is located just 5° due west from Psi, and is certainly one of the best globulars in the sky, ranking with M-13, Omega Centauri, and M-22. Regarded as one of the most ancient globulars, M-5, like all such objects, probably originated very early in the history of the universe. With a good pair of binoculars, you can catch a glimpse of this 6th magnitude object as a starry fuzz-ball. With telescopes 4 inches or larger, you can begin to resolve individual stars.

Gottfried Kirch, the director of the Royal Observatory in Berlin, is credited with discovering this object in 1702. Messier rediscovered this globular in 1764, recording it as a "fine nebula, which I am sure contains no star." In 1924 Mary Proctor wrote in her book, *Evenings with the Stars*, about her view of M-5 through the Yerkes 40-inch refractor: "Myriads of glistening points shimmering over a soft background of starry mist, illumined as though by moonlight, formed a striking contrast to the darkness of the night sky. For a few blissful moments, during which the watcher gazed at this scene, it suggested a veritable glimpse of the heavens beyond." That description is what deep-sky observing is all about.

corona borealis/serpens caput



40°
17h
15h
14h
Corona Borealis
M-13
σ
ξ
η
β
R
γ
α
T
30°
Bootes
Serpens Caput
Hercules
π
20°
Arcturus
κ
β
R
λ
δ
10°
Ophiuchus
λ
α
Virgo
M-5
ψ
0°
celestial equator
M-12
M-10
16h

Object	Type	Mag.	Size/Sep. Per.	R.A. (1950)	Dec.	R.A. (2000)	Dec.
M-5	●	6.0	20′	15h16m	+2°16′	15h19m	+2°05′
Eta (η) CrB	★^{2}	5.7,6.0	0.7″	15h21m	+30°28′	15h23m	+30°17′
CrB galaxy cluster	—	15	30′	15h21m	+27°50′	15h23m	+27°39′
Alpha (α) CrB	★	2.2	—	15h33m	+26°53′	15h35m	+26°43′
Gamma (γ) CrB	★^{2}	4.2,5.6	0.3″	15h41m	+26°27′	15h43m	+26°18′
Psi (ψ) Ser	★^{4}	5.9,12	4″	15h42m	+2°40′	15h44m	+2°31′
Alpha (α) Ser	★^{2}	2.6,12	58″	15h42m	+6°35′	15h44m	+6°26′
Beta (β) Ser	★^{2}	3.7,9	31″	15h44m	+15°35′	15h46m	+15°25′
R CrB	∩★	6-12.5	irr.	15h47m	+28°19′	15h49m	+28°09′
R Ser	ᗰ★	5.7-14	357d	15h48m	+15°17′	15h51m	+15°08′
T CrB	∩★	10-2	irr.	15h57m	+26°04′	16h00m	+25°55′
Sigma (σ) CrB	★^{2}	5.7,6.7	7″	16h13m	+33°59′	16h15m	+33°52′

★	*Star*
★^{2}	*Double Star*
★^{3}	*Triple Star*
ᗰ★	*Regular Variable*
∩★	*Irregular Variable*
Ӿ★	*Eclipsing Variable*
○	*Open Cluster*
●	*Globular Cluster*
■	*Planetary Nebula*
□	*Bright Diffuse Nebula*
§0	*Elliptical Galaxy*
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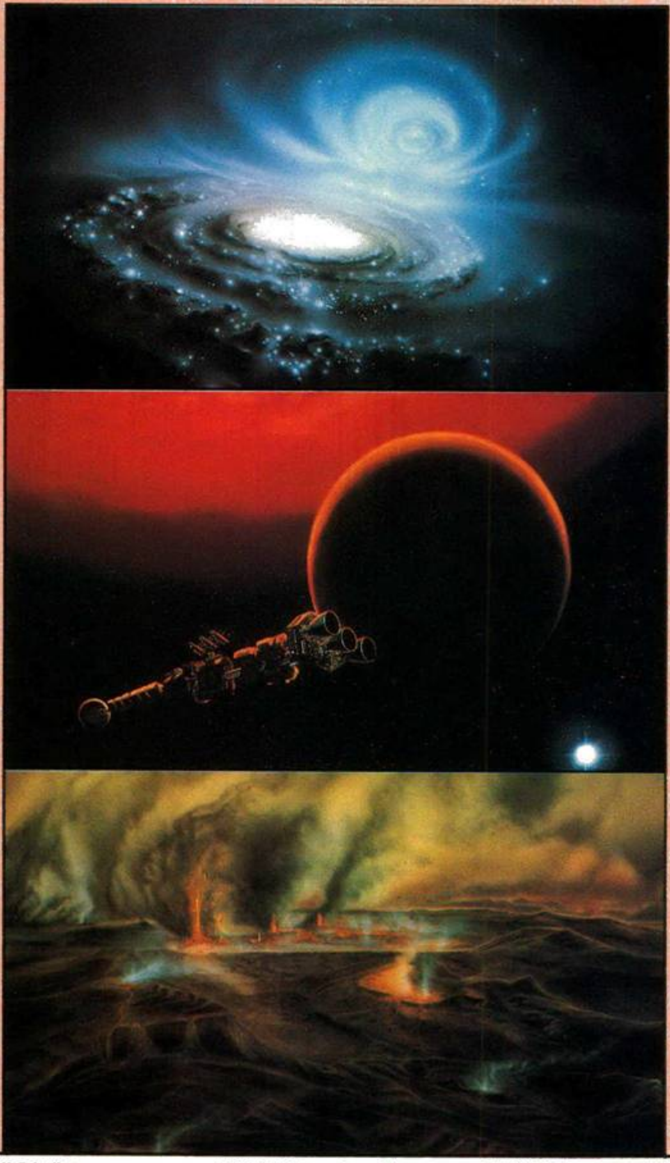

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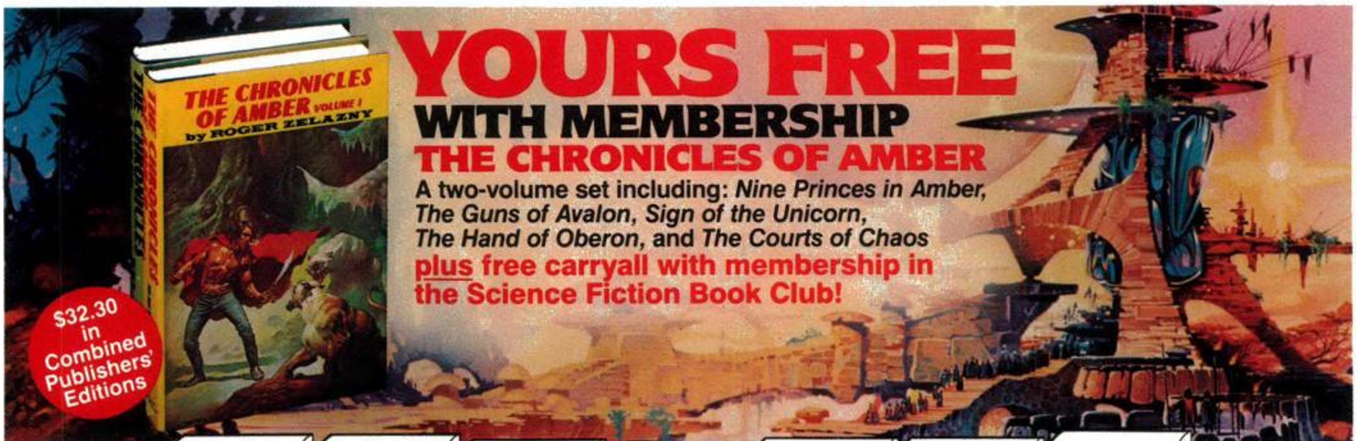
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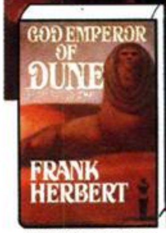
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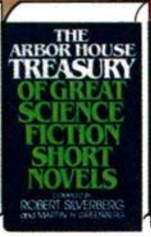
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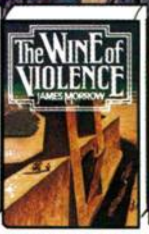
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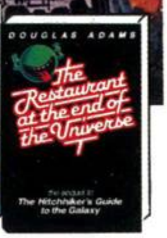
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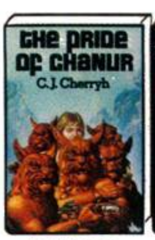
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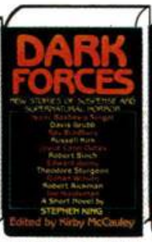
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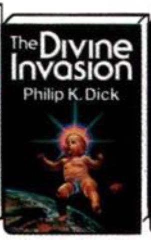
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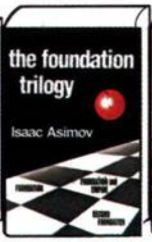
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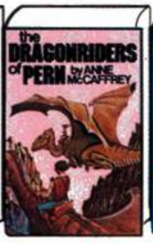
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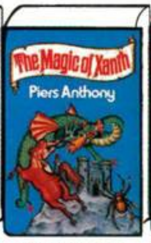
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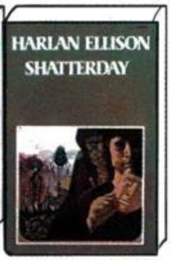
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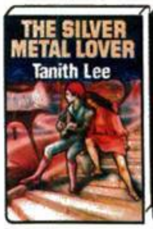
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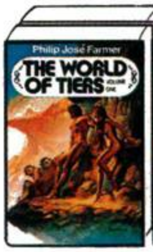
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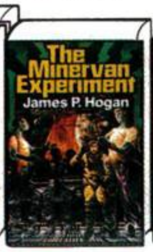
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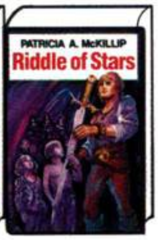
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